

Fiscal Year 2005 Environmental Monitoring Report for the Radioactive Waste Management Complex

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June 2006

**Idaho
Cleanup
Project**

The Idaho Cleanup Project is operated for the
U.S. Department of Energy by CH2M ♦ WG Idaho, LLC

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**Idaho Cleanup Project
Operable Unit 7-13/14
Idaho Falls, Idaho 83415**

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Under DOE Idaho Operations Office
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ABSTRACT

This report summarizes Fiscal Year 2005 analytical monitoring data associated with contaminants of concern detected in the vadose zone and aquifer near the Idaho National Laboratory Site Radioactive Waste Management Complex. Historical data from Fiscal Years 1997 to 2005 are included to facilitate evaluation and discussion of temporal and spatial trends.

Analytical results for Fiscal Year 2005 show that (1) nitrate, uranium isotopes, various volatile organic compounds, and low concentrations of carbon-14 and technetium-99 were detected frequently in the vadose zone; (2) only carbon tetrachloride was detected consistently in the aquifer beneath the Radioactive Waste Management Complex; and (3) carbon tetrachloride was detected in many aquifer monitoring wells at concentrations near and occasionally exceeding the primary drinking water maximum contaminant level. Contaminants of concern detected in Fiscal Year 2005 are consistent with historical monitoring results and show no notable changes in concentration, except for increasing levels of uranium at one location in the vadose zone. Low concentrations of volatile organic compounds, fluoride, iron, sodium, and tritium also were detected at the same location.

Volatile organic compounds in the vadose zone are shown to be declining in soil-gas samples due to ongoing vapor vacuum extraction; however, it is not clear whether vapor vacuum extraction efforts have yet affected concentrations in the aquifer.

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FY	fiscal year
ICPMS	inductively coupled plasma-mass spectrometry
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LLW	low-level waste
MCL	maximum contaminant level
OU	operable unit
PA/CA	performance assessment and composite analysis
RTC	Reactor Technology Complex
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SVR	soil vault row
TRU	transuranic
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAG	waste area group

Fiscal Year 2005 Environmental Monitoring Report for the Radioactive Waste Management Complex

1. INTRODUCTION

Waste disposal operations have been conducted at the Idaho National Laboratory (INL) Site Radioactive Waste Management Complex (RWMC) (see Figure 1-1) since the 1950s. Contaminant concentrations are monitored routinely near RWMC in soil gas (i.e., vapor), soil moisture (i.e., water that accumulates in soil pores), and in the Snake River Plain Aquifer to determine whether waste buried in the Subsurface Disposal Area (SDA) (see Figure 1-2) within RWMC is impacting the environment. In addition, occasional special studies are conducted to determine whether contaminants can be detected in the atmosphere and other media. Results from these monitoring activities are used to support the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980) risk assessment for the Waste Area Group (WAG) 7 CERCLA Remediation Project (hereafter referred to as the WAG 7 Project) and the Performance Assessment and Composite Analysis (PA/CA) Monitoring Program of the Landfills and Waste Disposal Project.

This report compiles environmental monitoring results for RWMC, which comprises WAG 7, for Fiscal Year (FY) 2005 (i.e., October 2004 through September 2005) and includes historical data to FY 1996, where appropriate. Historical monitoring data are rather voluminous; because these data are documented, presented, and can be referenced in the Remedial Investigation and Baseline Risk Assessment (Holdren et al. 2006), historical data will not be included in future RWMC annual reports. Together, the Remedial Investigation and Baseline Risk Assessment and this FY 2005 Annual Monitoring Report compile all available monitoring data from 1971 through FY 2005 and will, therefore, provide a comprehensive reference of historical data for the FY 2006 annual report.

1.1 Purpose and Scope

Monitoring results summarized in this report are used to satisfy several requirements. The Landfills and Waste Disposal Project uses the results to comply with requirements of U.S. Department of Energy (DOE) Order 435.1 and the associated implementation manual and guidance, which require monitoring of low-level radioactive waste disposal facilities. In particular, the following requirements of DOE Order 435.1 must be addressed:

- Site-specific PA/CA will be used to determine media, locations, radionuclides, and other substances to be monitored.
- The Environmental Monitoring Program will be designed to include measuring and evaluating releases and migration of radionuclides.
- The Environmental Monitoring Program will be capable of detecting changing trends in performance to allow application of necessary corrective action before exceeding performance assessment objectives (i.e., action levels). Performance assessment objectives for FY 2005 are discussed and compared with monitoring results in the PA/CA review for FY 2004 (Parsons, Seitz, and Keck 2005).

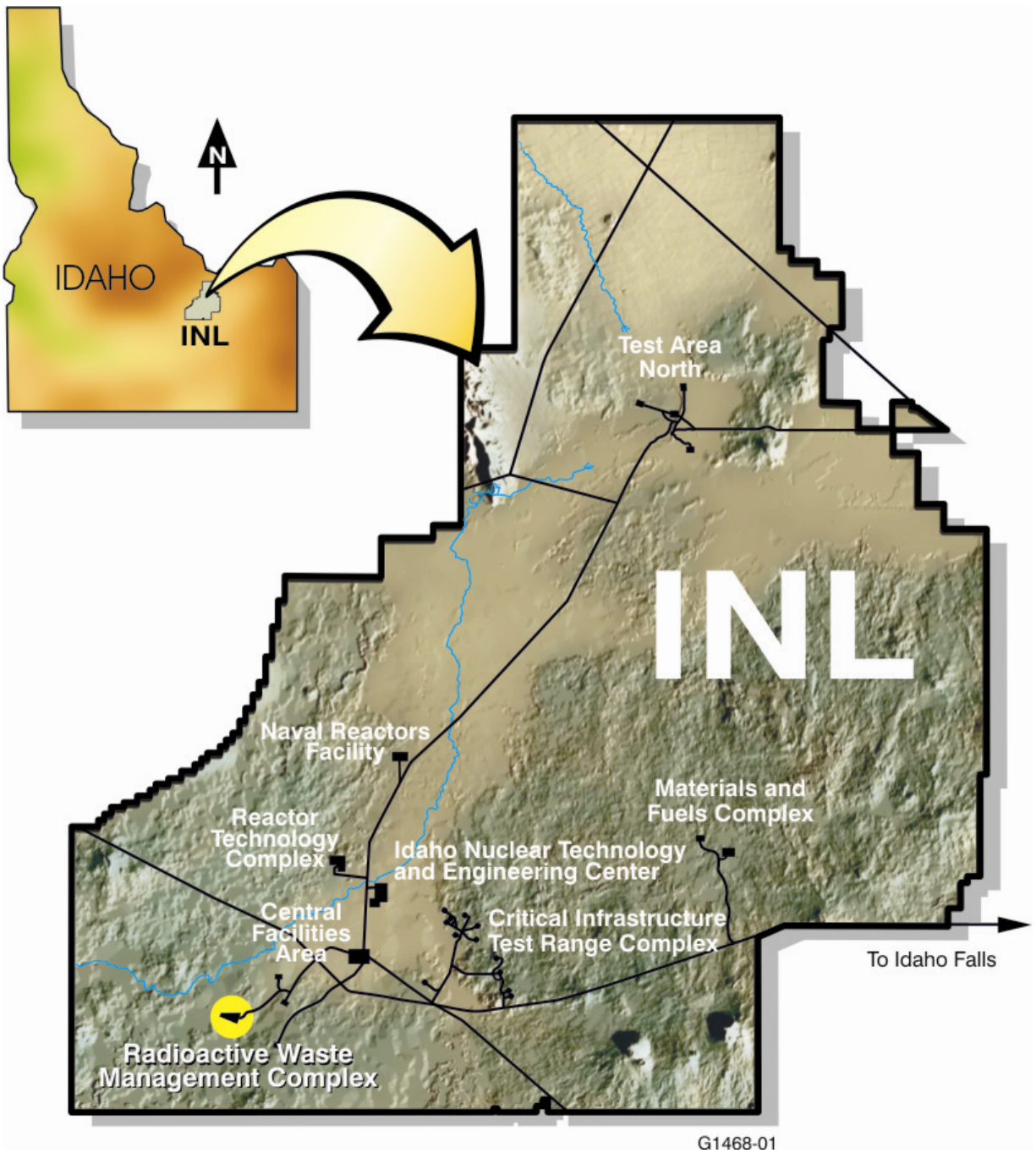
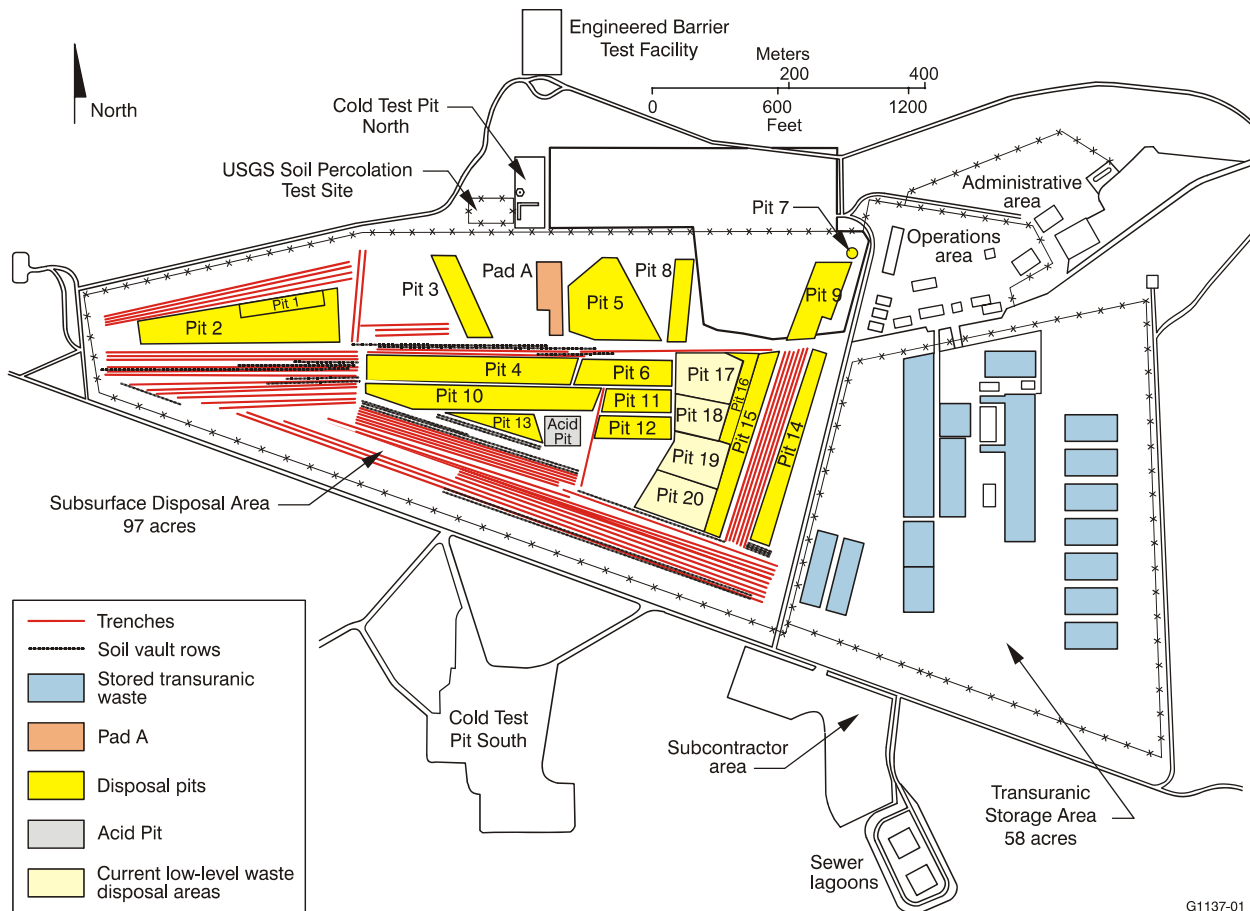


Figure 1-1. Idaho National Laboratory Site showing locations of the Radioactive Waste Management Complex and other Site facilities.



G1137-01

Figure 1-2. Radioactive Waste Management Complex showing the Subsurface Disposal Area.

The WAG 7 Project uses monitoring results to support activities associated with the ongoing CERCLA remedial investigation and feasibility study for WAG 7. Operable Unit (OU) 7-13/14 is the designation for the comprehensive OU for WAG 7 recognized under the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991) and CERCLA.

Environmental monitoring data are used to support the following OU 7-13/14 objectives:

- Assess environmental distributions of contaminants associated with RWMC
- Monitor for evidence of contaminant migration to support efforts to protect the Snake River Plain Aquifer
- Provide monitoring data to INL oversight groups and regulatory agencies (i.e., DOE, the Idaho Department of Environmental Quality, and the U.S. Environmental Protection Agency [EPA])
- Provide baseline data to support remedial decisions in the upcoming comprehensive record of decision for OU 7-13/14 and evaluate effectiveness of remedial actions
- Assess historical fate and transport model performance.

The remainder of this report is organized in the following manner:

- Section 2 discusses changes to the reporting protocol and the Routine Monitoring Program, which focuses on sampling the vadose zone and aquifer
- Section 3 presents the nature and extent of contamination for contaminants relevant to remedial decision-making and operation of the Low-Level Waste (LLW) Disposal Facility (i.e., LLW Pit) at RWMC (see Table 1-1)
- Section 4 provides complete reference information for sources cited within the document.

Table 1-1. Analytes relevant to remedial decision-making or operation of the Low-Level Waste Disposal Facility.

Analyte	Remedial Decision-Making ^a	Low-Level Waste Disposal Facility Operations ^b
Ac-227 ^c	✓	—
Am-241	✓	—
C-14	✓	✓
Cl-36	—	✓
Cs-137	✓	—
I-129	✓	✓
Np-237	✓	✓
Pa-231 ^c	✓	—
Pb-210 ^c	✓	—
Pu-238 ^d	—	—
Pu-239/240	✓	—
Ra-226 ^c	✓	—
Ra-228 ^c	✓	—
Sr-90	✓	—
Tc-99	✓	—
Th-228	✓	—
U-233/234 ^e	✓	✓
U-235/236 ^e	✓	—
U-238 ^e	✓	✓
Carbon tetrachloride	✓	—
1,4,-Dioxane	✓	—
Methylene chloride	✓	—
Nitrate ^e	✓	—
Tetrachloroethylene	✓	—

a. Analytes relevant to remedial decision-making are based on the Remedial Investigation and Baseline Risk Assessment (Holdren et al. 2006).

b. Analytes relevant to low-level waste disposal operations are based on the Performance Assessment and Composite Analysis (McCarthy, Seitz, and Ritter 2000), which is currently under revision.

c. Monitoring is not routinely performed for these analytes; however, Ra-226 is indirectly analyzed (see discussion in Section 3.9).

d. Not a contaminant of concern, but analyzed and reported in conjunction with Pu-239/240.

e. Uranium-233/234, -235/236, -238, and nitrate are naturally occurring in the environment, and measured results are reported if concentrations exceed their respective upper background concentration range (shown in Table 2-2).

— = indicates analyte is not relevant.

2. MONITORING AT THE RADIOACTIVE WASTE MANAGEMENT COMPLEX

Environmental samples are routinely collected in the SDA vadose zone and aquifer near the RWMC area and analyzed for a variety of radionuclide, inorganic, and organic contaminants relevant to remedial decision-making and operation of the LLW Disposal Facility at RWMC (see Table 1-1). Section 2.1 defines relevant analytes. Routine monitoring of vadose zone and aquifer samples includes analyses of 26 radionuclides, 28 volatile organic compounds (VOCs), and 29 inorganic constituents. Many of these are not relevant analytes, but are included as part of the analytical laboratory's routine analyses suites required by EPA Contract Laboratory Program Target Analyte/Compound Lists. Section 3 describes the soil-moisture, soil-gas, and aquifer monitoring networks.

In FY 2005, routine monitoring of the vadose zone and aquifer beneath RWMC generated over 8,000 sample analysis results, each of which provided information for assessing the nature and extent of contamination and determining the migratory status of relevant analytes. Results for each relevant analyte are presented by monitoring zone: (1) vadose zone and (2) aquifer. Subsurface monitoring zones are divided into distinct regions, as shown in Figure 2-1, and monitoring data are reported according to depth intervals where samples were obtained. Included in the vadose zone monitoring intervals are three sedimentary interbeds, located at depths around 9, 34, and 73 m (30, 110, and 240 ft), and referred to as the A-B, B-C, and C-D interbeds, respectively. The A-B, B-C, and C-D nomenclature was derived from the basalt flow groups (i.e., A, B, C, and D) that bound the sedimentary layers immediately above and below. Vadose zone depth intervals are detailed below and illustrated in Figure 2-1:

- **0 to 11 m (0 to 35 ft)**—Vadose zone samples from this depth interval were located some distance away from waste disposals and between, beside, or away from pits or trenches in the SDA. Analytical data in this depth interval for FY 2005 are from soil-moisture samples collected using suction lysimeters (see lysimeter locations in Figure 2-2), and vapor ports (see Figures 2-3 and 2-4).
- **11 to 43 m (35 to 140 ft)**—The intermediate-depth interval includes the A-B and B-C interbeds. Fiscal Year 2005 analytical data in this depth interval are from soil-moisture samples collected using suction lysimeters (see Figure 2-5) and vapor ports (see Figures 2-3 and 2-4).
- **43 to 76 m (140 to 250 ft)**—This interval includes the C-D interbed. Fiscal Year 2005 analytical data in this depth interval are from perched water wells and soil-moisture samples collected using suction lysimeters (see Figure 2-6) and vapor ports (see Figures 2-3 and 2-4).
- **76 to 177 m (250 to 580 ft), with 13 lysimeters 82 to 126 m (270 to 413 ft) deep**—Deep monitoring lysimeters were installed in 2003 and 2004. In FY 2005 analytical data in this depth interval are from soil-moisture samples collected using suction lysimeters (see Figure 2-6) and vapor ports (see Figures 2-3 and 2-4).
- **Aquifer**—WAG 7 routinely monitors 15 monitoring wells in the aquifer near RWMC, while the U.S. Geological Survey (USGS) routinely samples eight monitoring wells near RWMC (see Figure 2-7).

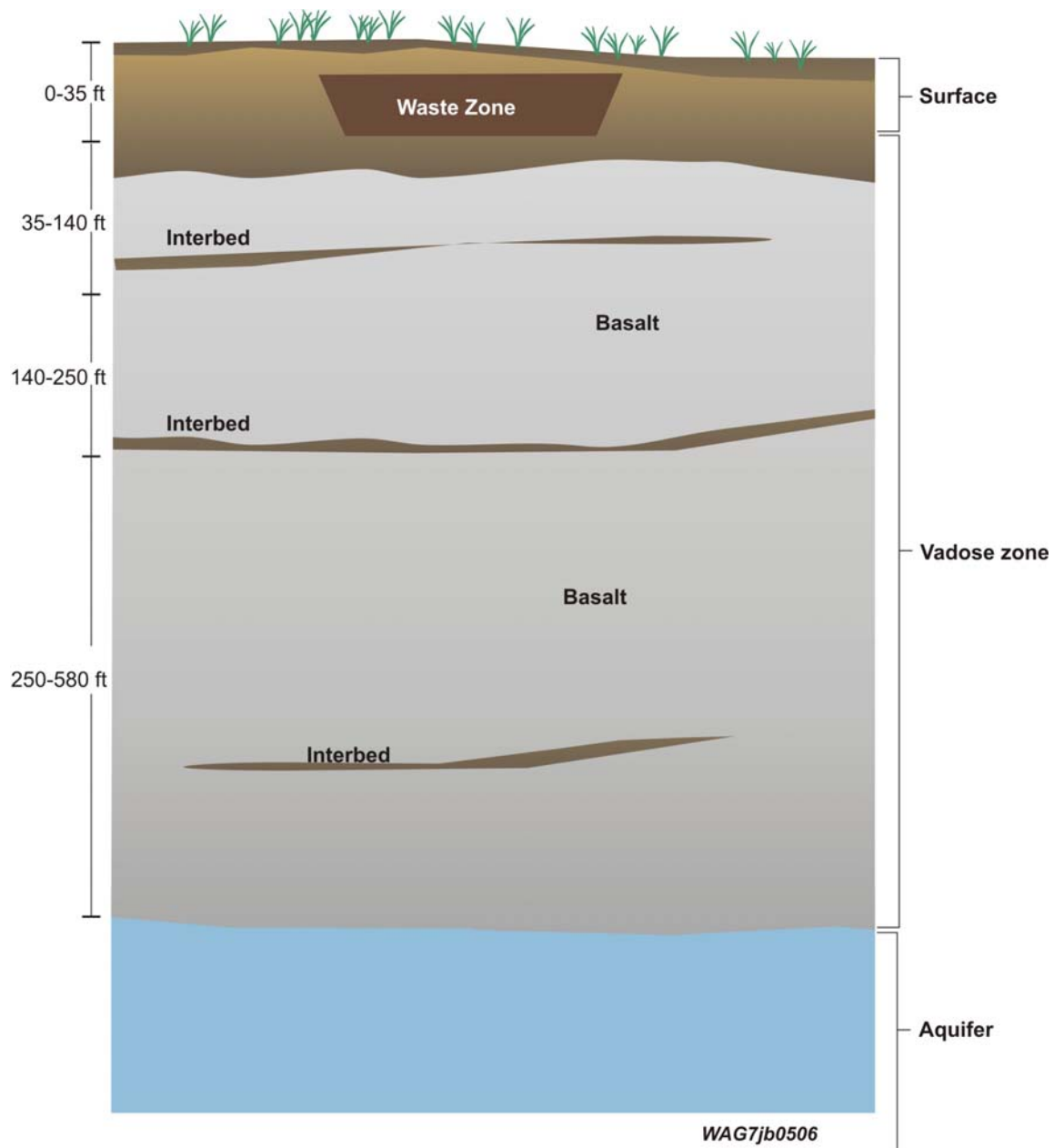


Figure 2-1. Depth intervals analyzed to evaluate nature and extent of contamination.

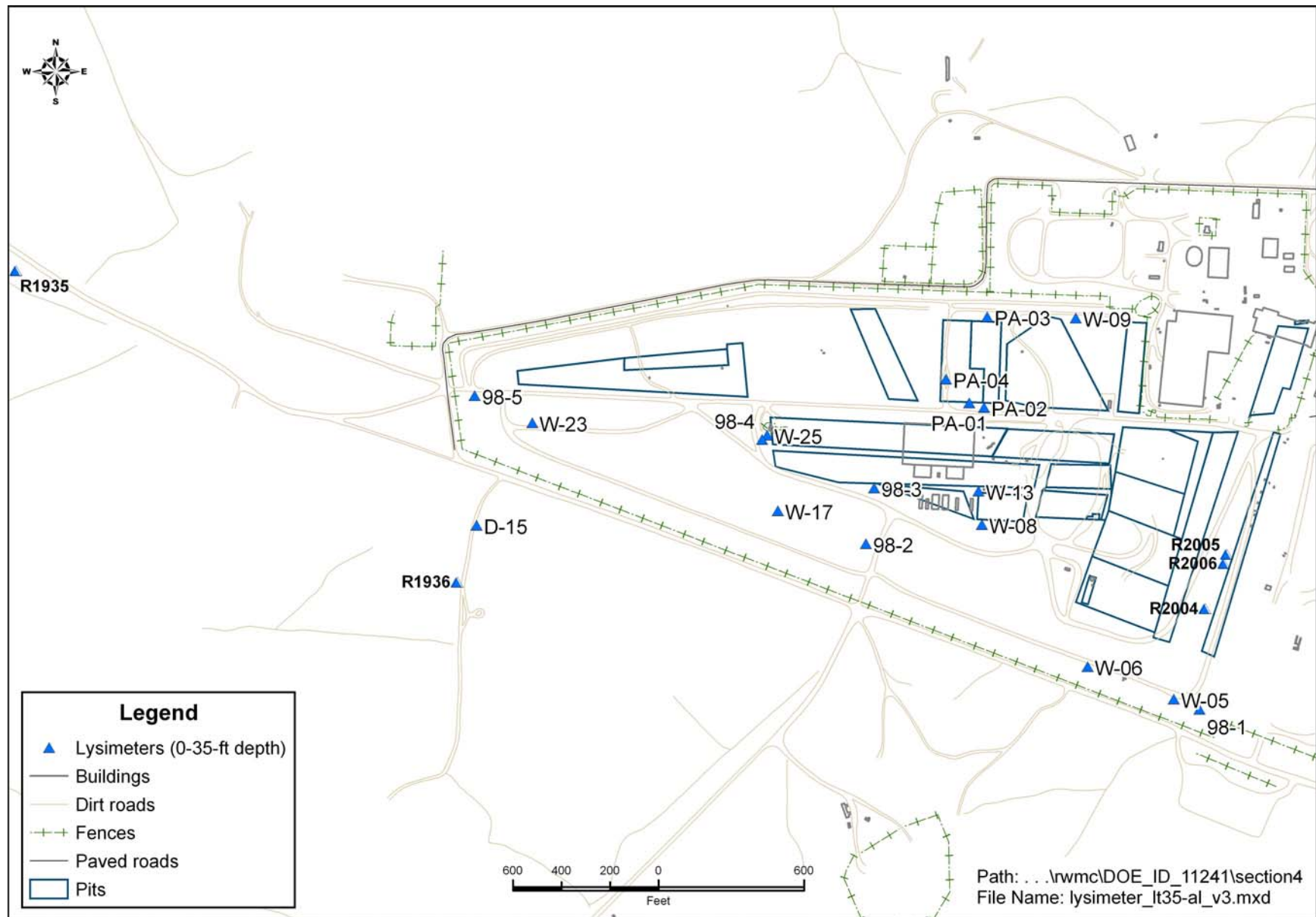


Figure 2-2. Wells with lysimeters located in the shallow-depth (0 to 35 ft) vadose zone.

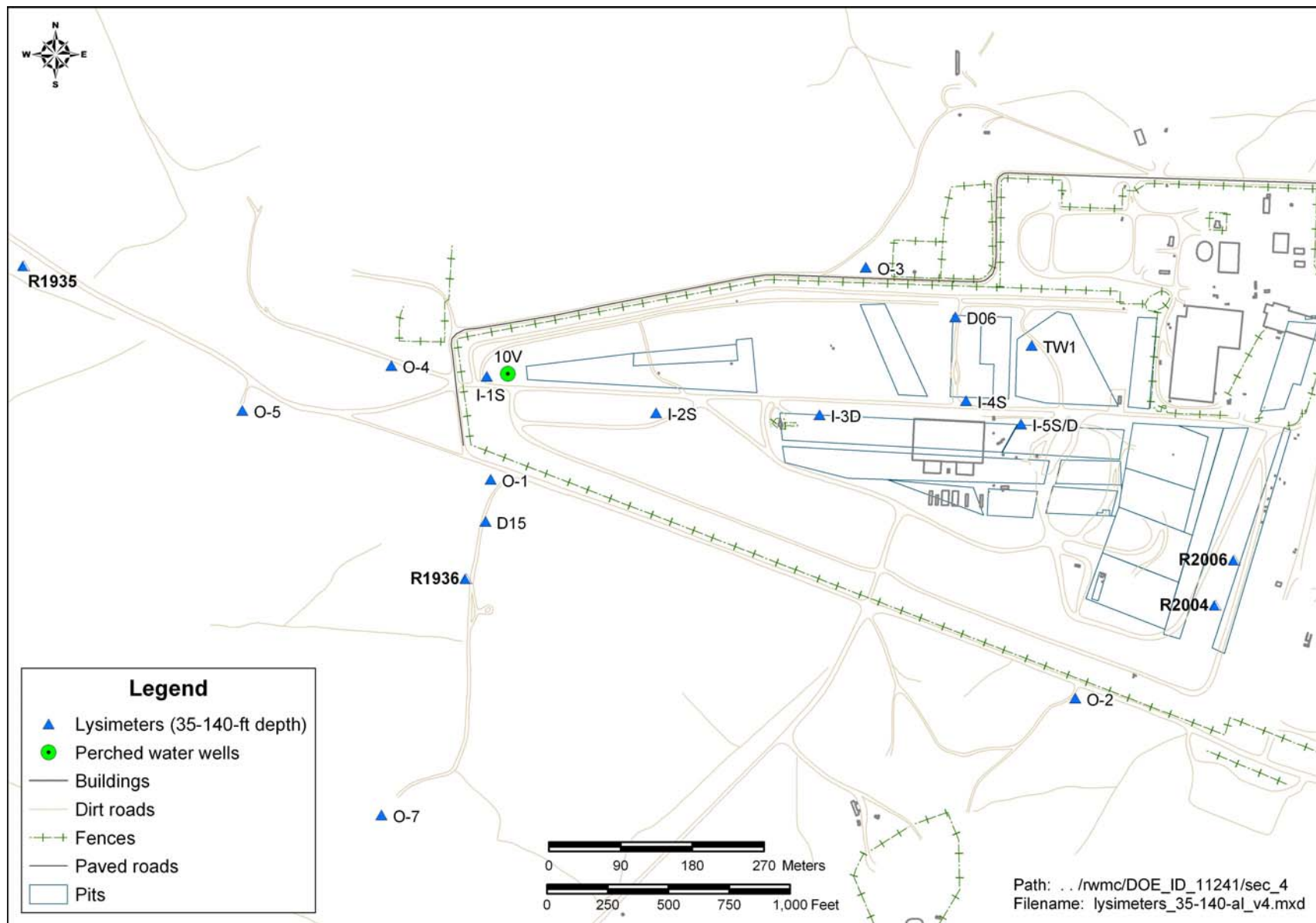


Figure 2-3. Wells with lysimeters located in the intermediate-depth (35 to 140 ft) vadose zone.

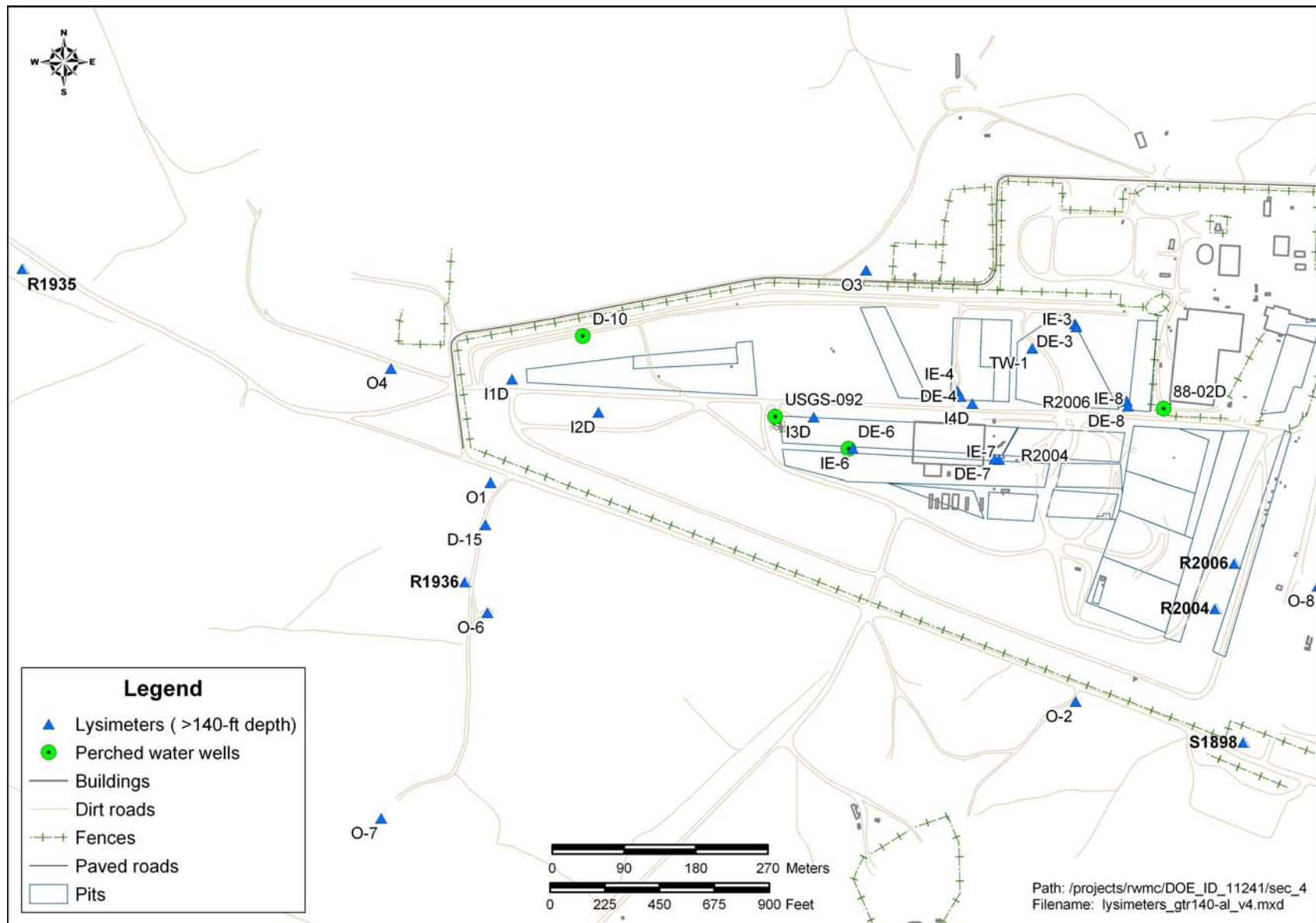


Figure 2-4. Wells with lysimeters located in the deep (greater than 140 ft) vadose zone.

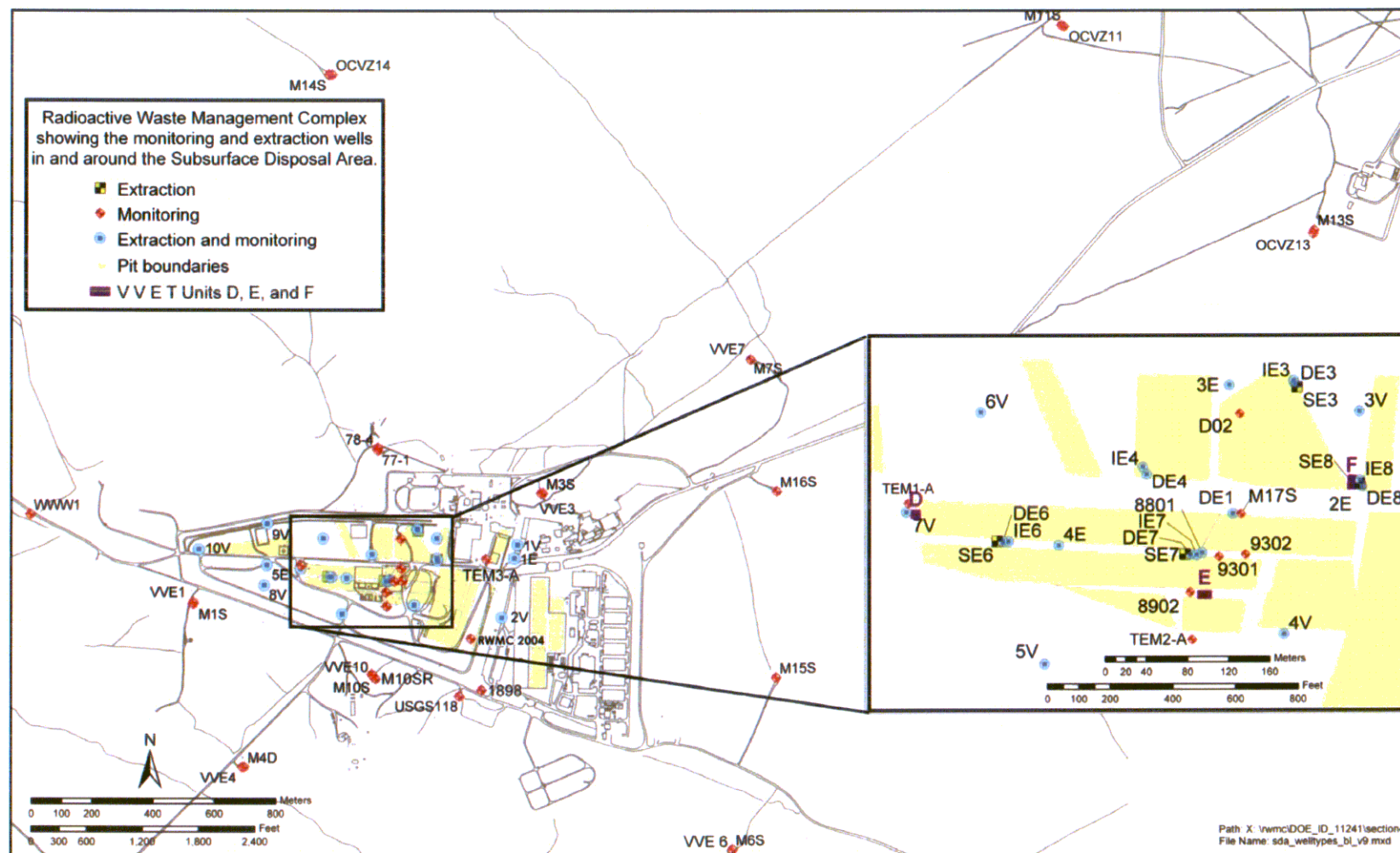


Figure 2-5. Wells near the Subsurface Disposal Area with permanent vapor sampling ports.

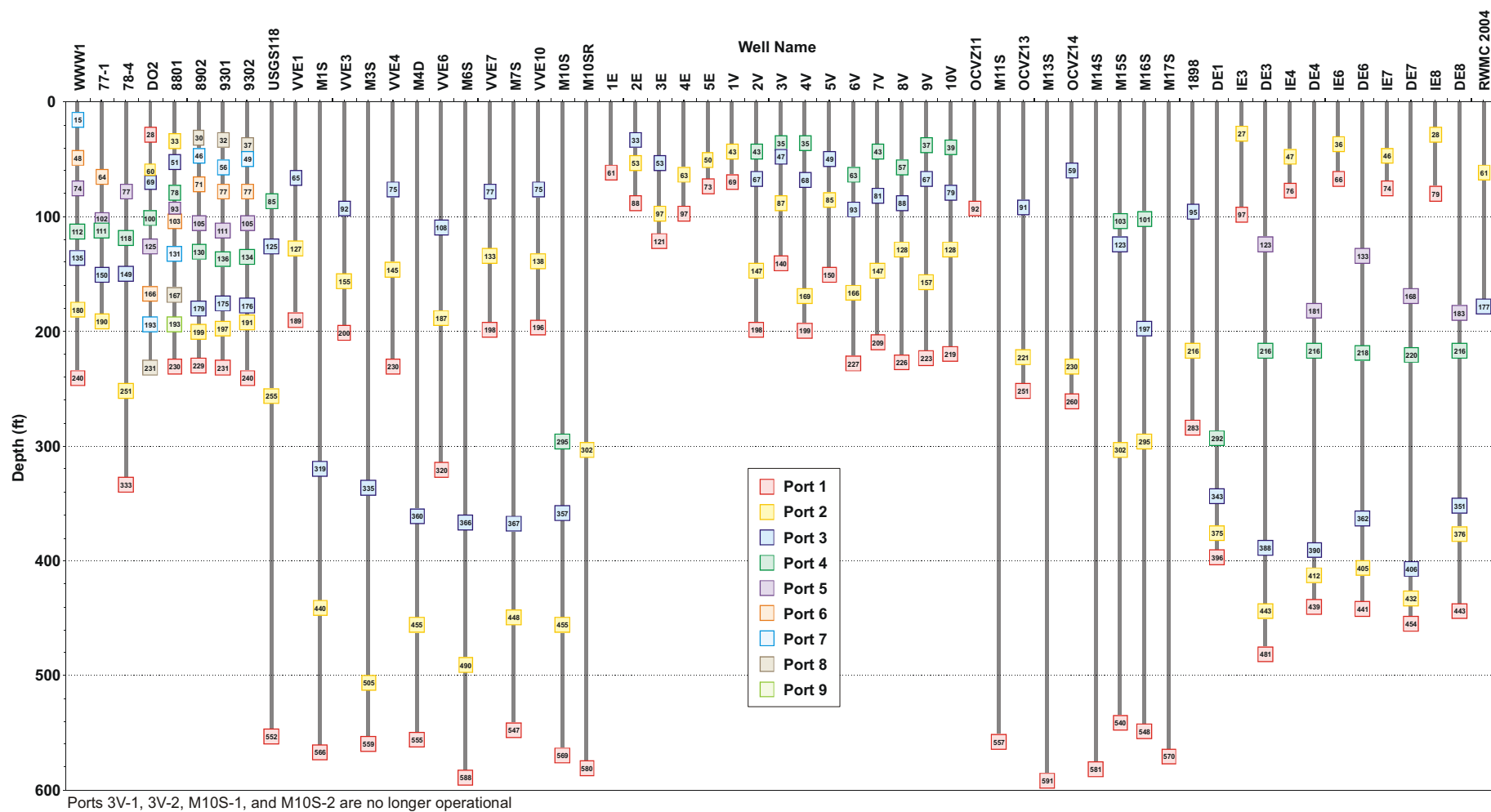


Figure 2-6. Identifiers and depths of vapor sampling ports at the Subsurface Disposal Area.

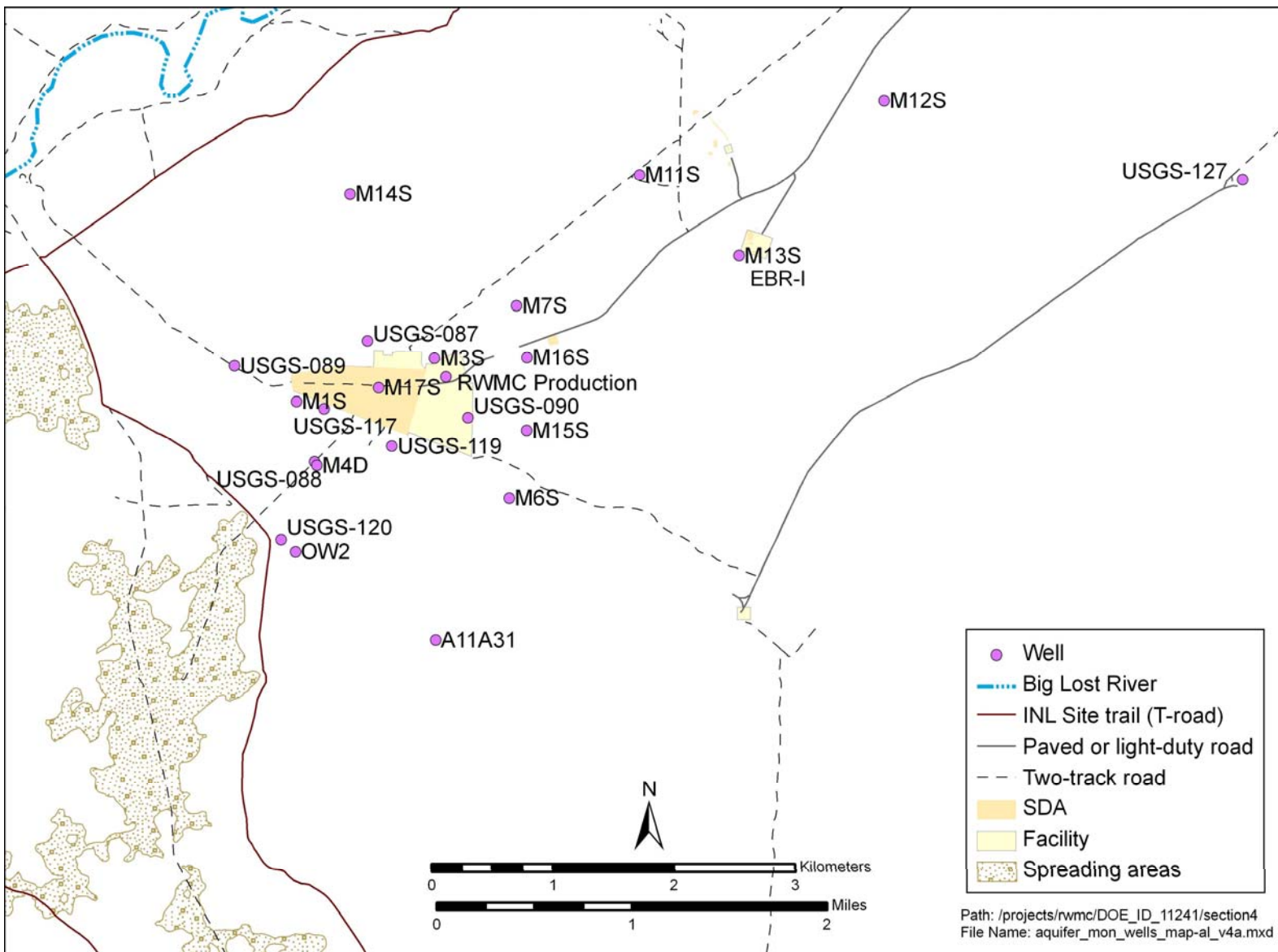


Figure 2-7. Aquifer monitoring wells at the Radioactive Waste Management Complex.

2.1 Relevant Analytes

Three types of relevant analytes (i.e., radionuclides, inorganic chemicals, and VOCs) are sampled, analyzed, and interpreted under different protocols, as described in discussions that follow. These relevant analytes may be released from their sources and migrate either upward to the surface or downward through the vadose zone and into the aquifer. Ultimately, these analytes pose a threat or risk to human health or the environment.

Monitoring priorities were established through collaboration between the WAG 7 and Landfills and Waste Disposal projects and other data users. McCarthy, Seitz, and Ritter (2001) identified data required for the RWMC PA/CA Monitoring Program.

Sample volumes often are limited for soil-moisture and perched water samples; therefore, analytical priorities are established for target contaminants that will best utilize the volume available to meet sampling and analytical objectives. Table 2-1 identifies analytical priorities for perched water and soil moisture (Koeppen and McIlwain 2005).

2.2 Reporting Protocol

Historically, OU 7-13/14 quarterly and annual monitoring reports address data for all analytes measured at concentrations greater than background. This reporting protocol generated an inordinate amount of analytical data; and though interesting, findings and observations noted in past reports were not relevant to remedial decision-making or to operation of the RWMC LLW Disposal Facility. Therefore, the protocol was revised to focus primarily on relevant analytes (see Table 1-1) for comparison to primary drinking water maximum contaminant levels (MCLs) (see Table 2-2), regardless of exposure routes or exposure scenarios. Relevant analytes are constituents that meeting the following criteria:

1. Identified as contaminants of concern for remedial decision-making
2. Identified as contaminants of interest for LLW disposal
3. Associated decay chain members of Items (1) or (2)
4. Any constituent that exhibits meaningful trends or concentrations approaching MCLs. Note that soil moisture and perched water beneath RWMC are not viable sources of drinking water; MCLs are used only for comparison as a screening tool to filter for concentration results of interest.

Relevant analytes that have a background component in the environment (see Table 1-1) will be reported only if their concentrations exceed local soil-moisture upper-background concentrations (see Table 2-2). Other analytes (e.g., chromium, chloride, sulfate, and tritium) will be reported only if (1) sustained trends in concentration are observed or (2) concentrations approach regulatory limits. All other constituents will be excluded from quarterly reports; however, complete data sets (e.g., detections, nondetections, and associated detection limits) will be available in limitations and validation reports.

Table 2-1. Analytical priorities for routine analyses of perched water and soil moisture.

Analysis Priority	Preservative	Contract-Required Detection Limit (pCi/L or mg/L) ^a	Sample Volume (mL)	Justification
Gamma emitters/ Tc-99	HNO ₃ to pH < 2	<200 (gamma) <15 (Tc-99)	50	Cesium-137 and Ra-226 are relevant gamma-emitting radionuclides. Gamma spectroscopy is a nondestructive analysis that provides data on relevant analytes plus any other detected gamma-emitting radionuclide. Technetium-99 is a relevant analyte and is highly mobile ($K_d \sim 0$ mL/g). Technetium-99 is detected in the vadose zone (i.e., core, soil-moisture, and perched water samples). Technetium-99 is consistently detected at two vadose zone monitoring locations.
Uranium, plutonium, and americium	HNO ₃ to pH < 2	<2/each	50	Uranium isotopes, plutonium-239/240, and americium-241 are relevant analytes. Uranium is consistently detected above background and U.S. Environmental Protection Agency MCLs at various locations. Plutonium-238 is not a contaminant of concern, but analyzed and reported in conjunction with plutonium 239/240.
C-14	None	<50	50	Carbon-14 is a relevant analyte, is highly mobile ($K_d \sim 5$ mL/g), and is detected in the vadose zone (i.e., perched water and soil-moisture samples).
Anions	4°C	0.5	25	Nitrate is a relevant analyte and is detected in the vadose zone at a few locations with concentrations above the MCL. Chloride, bromide, and sulfate, are detected at concentrations greater than background throughout the vadose zone, and are components of magnesium chloride, which was applied to roads. Chloride also serves as a water tracer.
Metals	HNO ₃ to pH < 2	See Table 2-2	25	Metals are not relevant analytes; however, magnesium, sodium, calcium, and potassium are detected at concentrations greater than background throughout the vadose zone and are primarily associated with magnesium chloride brine.
Tritium	None	<250	50	Tritium is not a relevant analyte, but is frequently detected at low concentrations in the vadose zone (i.e., perched water and soil-moisture) samples. Tritium concentrations are near the MCL at location R2006 at the eastern end of the Subsurface Disposal Area.
Cl-36	HNO ₃ to pH < 2	100	50	Chlorine-36 is a relevant analyte and is infrequently detected in the vadose zone.
I-129	None	<40	50	Iodine-129 is a relevant analyte, is highly mobile ($K_d \sim 0.1$), and is seldom detected in vadose zone soil-moisture samples.
Np-237	HNO ₃ to pH < 2	<2	50	Neptunium-237 is a relevant analyte, is highly mobile ($K_d \sim 8$), and is not detected in the vadose zone.

Note: Priorities for excess sample volume are determined for each round, based on potential emerging trends.

a. Required detection limits are as low as reasonably achievable, considering the extremely limited sample volume.

MCL = maximum contaminant level

Table 2-2. Comparison concentrations for soil moisture, perched water, and groundwater media for Fiscal Year 2005.

Contaminant	Local Soil-Moisture Background ^a	Aquifer Background		Maximum Contaminant Level for Water ^d
		Concentration Range ^b	Concentration Range Most Commonly Observed ^c	
Ac-227	NE	NE	NE	NE
Am-241	ND	ND	ND	15 pCi/L (total alpha)
C-14	ND	NE	NE	2,000 pCi/L
Cl-36	ND	NE	NE	700 pCi/L
Cs-137	ND	ND	ND	200 pCi/L
Tritium	ND	0 to 134 pCi/L	0 to 40 pCi/L	20,000 pCi/L
I-129	ND	ND	ND	1 pCi/L
Np-237	ND	NE	NE	15 pCi/L (total alpha)
Pa-231	NE	NE	NE	15 pCi/L (total alpha)
Pb-210	NE	NE	NE	NE
Pu-238	ND	ND	ND	15 pCi/L (total alpha)
Pu-239/240	ND	ND	ND	15 pCi/L (total alpha)
Ra-226	NE	0.01 to 0.37 pCi/L	0 to 0.1 pCi/L	5 pCi/L (total radium)
Ra-228	NE	0 to 2.7 pCi/L	0 to 0.3 pCi/L	5 pCi/L (total radium)
Sr-90	ND	ND	ND	8 pCi/L
Tc-99	ND	NE	NE	900 pCi/L
Th-228	NE	NE	NE	NE
U-233	NA	NA	NA	NA ^e
U-234	0 to 8.52 pCi/L	NE 0.38 to 1.69 pCi/L ^f UTL = 1.92 pCi/L ^g	NE	NA ^e
U-235	0 to 1.34 pCi/L	NE 0.01 to 0.15 pCi/L ^f UTL = NE ^g	NE	NA ^e
U-236	NA	NA	NA	NA ^e
U-238	0 to 3.86 pCi/L	NE 0.17 to 0.90 pCi/L ^f UTL = 0.90 pCi/L ^g	NE	NA ^e

Table 2-2. (continued).

Contaminant	Local Soil-Moisture Background ^a	Aquifer Background		Maximum Contaminant Level for Water ^d
		Concentration Range ^b	Concentration Range Most Commonly Observed ^c	
Uranium (total)	0 to 11.7 µg/L	0 to 7.0 µg/L 0.5 to 2.7 µg/L ^f 0.3 to 3.6 µg/L ^h	0 to 3 µg/L	30 µg/L
Chromium (total)	0 to 13 µg/L	NE 1 to 22 µg/L ⁱ	NE	100 µg/L
Carbon tetrachloride	NA ^j	<0.2 µg/L	NE	5 µg/L
1,4-Dioxane	NA ^j	NE	NE	NE ^k
Methylene chloride	NA ^j	<0.2 µg/L	NE	5 µg/L
Nitrate-N	0 to 11.4 mg/L	0 to 5 mg/L	1 to 2 mg/L	10 mg/L
Tetrachloroethylene	NA ^j	<0.2 µg/L	NE	5 µg/L
Trichloroethylene	NA ^j	<0.2 µg/L	NE	5 µg/L

a. Concentration range from Koeppen et al. 2005.
 b. Concentration range from Knobel, Orr, and Cecil (1992).
 c. Concentration range from 1 of Knobel, Orr, and Cecil (1992).
 d. MCL from “National Primary Drinking Water Standards” (40 CFR 141) and *Implementation Guidance for Radionuclides* (EPA 2002).
 e. MCL is not applicable to individual uranium isotopes, only to total uranium. To account for individual isotopes, detected U-233/234 is assumed to be U-234, and U-235/236 is assumed to be U-235, which is conservative and consistent with natural uranium; isotopic activities for U-234, -235, and -238 are then converted to mass, combined, and compared to the 30-µg/L MCL for total uranium.
 f. Concentration range of aquifer monitoring wells near the Radioactive Waste Management Complex from 1998 through May 2005.
 g. UTL from Leecaster, Koeppen, and Olson 2003. UTL for U-235 was not established because most U-235 data are nondetections and yield large statistical variances. Therefore, the maximum concentration value is used as the UTL for U-235.
 h. Concentration range of aquifer monitoring wells at the Idaho National Laboratory Site (Roback et al. 2001).
 i. Reduction to value from Knobel et al. (1999) to exclude high-chromium data near the Reactor Technology Complex (known source of chromium). Range is for total chromium.
 j. Carbon tetrachloride, 1,4-dioxane, methylene chloride, tetrachloroethylene, and trichloroethylene do not occur naturally, and true background concentration should be zero; however, they may be found in the environment at trace concentrations because of use in a wide variety of industrial and household products.
 k. MCL has not been established for 1,4-dioxane, but the U.S. Environmental Protection Agency has issued a health-based advisory level of 3 µg/L for drinking water.
 MCL = maximum contaminant level
 NA = not applicable
 ND = nondetect; does not satisfy criteria for reportable detections (i.e., $X \leq 3\sigma < \text{minimum detectable activity}$).
 NE = not established
 UTL = upper tolerance limit

3. NATURE AND EXTENT OF CONTAMINATION

This section presents monitoring data for relevant analytes from samples collected in the vadose zone and aquifer in FY 2005. Data from past monitoring are included in cases of historical contaminants and monitoring locations with concentrations significantly greater than background levels, exceeding MCLs, or exhibiting trending concentrations. These data and discussions center primarily on results from routine aquifer and vadose zone monitoring conducted by the Idaho Cleanup Project. Discussions are tailored to address any trends or patterns in the data. Graphs, tables, and illustrations of patterns of contaminants in the environment are presented when data sets are large enough.

As discussed in Section 2.2, the reporting protocol was revised to focus primarily on relevant analytes for comparison to primary drinking water MCLs, regardless of exposure routes or exposure scenarios. Relevant analytes also are discussed in Section 2.2.

In FY 2005, analytical data were obtained from vadose zone vapor ports, vadose zone lysimeters, perched water wells, and aquifer monitoring wells. Also, C-14 and tritium soil-gas and ambient-air data were obtained at locations near SVR 12 and SVR 20.

Data are presented in the following sections according to the depth interval from which FY 2005 samples were obtained, beginning with the shallowest monitoring region (i.e., 0 to 35 ft) to the deepest (i.e., aquifer).

3.1 Americium-241

Americium-241 is an anthropogenic transuranic (TRU) radionuclide that is a decay product of Pu-241. It decays by the emission of alpha particles and has a half life of 432.7 years. This section provides a summary of americium monitoring data for all media, and data in this section are evaluated against comparison concentrations in Table 2-2.

CAVEAT: *Some low-level detections of Am-241 could be false positives. A study conducted at the Savannah River Site shows the occurrence of false positive results for Am-241 can be fairly common at commercial laboratories (Kubilius et al. 2004). False positives for Am-241 determined by alpha spectroscopy are attributed to interference from small quantities of natural Th-228 that are not completely removed from the sample during the chemical separation process (Kubilius et al. 2004).*

3.1.1 Buried Waste Inventory

Approximately $2.30\text{E}+05$ Ci of Am-241 was buried in the SDA through 1999, and an additional 0.44 Ci is projected to be added by 2009, for a total of $2.30\text{E}+05$ Ci. The primary source of Am-241 in the SDA is Rocky Flats Plant Series 741 sludge (i.e., first stage wastewater sludge).

3.1.2 Vadose Zone

This section discusses historical and FY 2005 distributions of Am-241 in vadose zone soil moisture and perched water in shallow-depth, intermediate-depth, and deep intervals.

3.1.2.1 Lysimeter Samples at Depths from 0 to 35 ft. Between November 2004 and August 2005, 33 Am-241 analyses were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, with no positive detections.

Since 1997, 188 analyses for Am-241 were performed on shallow-depth lysimeter samples, with six positive detections ranging in concentration from 0.30 to 9.0 pCi/L. Table 3-1 presents historical data (i.e., since routine monitoring began in 1997) for Am-241 in shallow-depth vadose zone samples. Section 3.1.4 summarizes concentration ranges, detection rates, and MCL exceedances since monitoring began in 1997. As shown in Table 3-1, detections are sporadic, with no apparent trends or spatial pattern.

3.1.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 39 Am-241 analyses were performed on soil-moisture samples collected from 15 intermediate-depth lysimeters near RWMC, with no positive detections.

Since 1997, 156 analyses for Am-241 were performed on intermediate-depth lysimeter samples, with six positive detections ranging in concentration from 0.80 to 6.0 pCi/L. Table 3-2 presents historical data for Am-241 in intermediate-depth vadose zone samples since routine monitoring began in 1997. Section 3.1.4 summarizes concentration ranges, detection rates, and MCL exceedances since monitoring began in 1997. As shown in Table 3-2, detections are sporadic with no apparent trends or spatial pattern.

3.1.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 60 Am-241 analyses were performed on soil-moisture and perched water samples collected from 25 monitoring wells near RWMC, yielding no positive detections.

Since 1997, 172 analyses for Am-241 were performed on samples from deep lysimeters, yielding one positive detection with a concentration of 30 pCi/L. Table 3-3 presents historical data for Am-241 in the deep vadose zone since monitoring began in 1997. Section 3.1.4 summarizes concentration ranges, detection frequencies, and MCL exceedances since monitoring began in 1997. As shown in Table 3-3, detections are sporadic with no apparent trends or spatial pattern.

Table 3-1. Americium-241 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Americium-241 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																			
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																		
	2																		
	3																		
	4																		
1998	1																		
	2							4.2											
	3					9													
	4																		
1999	1			0.8														0.8	
	2																		
	3			0															
	4																		
2000	1																		
	2			0.3															
	3																		
	4																		
2001	1																		
	2																		
	3																		
	4																		

Table 3-1. (continued).

Americium-241 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																			
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2002	1																		
	2																		
	3																		
	4																		
2003	1																		
	2																		
	3																		
	4																		
2004	1																		
	2																		
	3																		
	4																		
2005	1																		
	2																		
	3																		
	4																		
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, the maximum contaminant level = 15 pCi/L (total alpha).																			
	Analysis was performed, but Am-241 was not detected.																		
	Am-241 was detected (pCi/L). Some reported results could be false positives (see caveat in Section 3.1).																		

Table 3-2. Americium-241 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Americium-241 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																		
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																	
	2																	
	3																	
	4																	
1998	1																	
	2																	
	3			2.4														
	4																	
1999	1	0.8																
	2																	
	3																	
	4																	
2000	1																	
	2																	
	3																	
	4																	
2001	1																	
	2																	
	3																	
	4																	

Table 3-2. (continued).

Americium-241 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																		
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
2002	1																	
	2																	
	3																	
	4																	
2003	1																	
	2																	
	3																	
	4																	
2004	1																	
	2																	
	3																	
	4																	
2005	1																	
	2																	
	3																	
	4																	
Note: The highest result is reported for duplicate samples or reanalysis.																		
For comparison, the maximum contaminant level = 15 pCi/L (total alpha).																		
	Analysis was performed, but Am-241 was not detected.																	
	Am-241 was detected (pCi/L). Some reported results could be false positives (see caveat in Section 3.1).																	

3.1.3 Aquifer

In 2005, 35 analyses for Am-241 were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, with no positive detections.

Since 1997, 596 analyses for Am-241 were performed on aquifer samples, resulting in 10 positive detections ranging in concentration from 0.026 to 1.97 pCi/L. Table 3-4 shows the distribution of Am-241 detections in aquifer samples since 1997. Section 3.1.4 summarizes concentration ranges, detection rates, and MCL exceedances since monitoring began in 1997. Historical results for aquifer samples show sporadic detections of Am-241, but no evident trends or spatial pattern.

Table 3-4. Americium-241 detections in aquifer monitoring wells since 1997.

Americium-241 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1										1.13						
	2																
	3										1.97						
	4																
1999	1																
	2																
	3			0.026													
	4																
2000	1																
	2																
	3																
	4											0.027					
2001	1																
	2																
	3																
	4							0.039					0.066				0.058
2002	1																
	2																
	3																
	4																

Table 3-4. (continued).

Americium-241 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, the maximum contaminant level = 15 pCi/L total alpha.																	
		Analysis was performed, but Am-241 was not detected.															
		Am-241 was detected (pCi/L). Some reported results could be false positives (see caveat in Section 3.1).															
		Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.															

3.1.4 Summary of Americium-241

Americium-241 was not detected in soil-moisture, perched water, or aquifer samples collected in FY 2005. The absence of detections at FY 2005 sampling locations demonstrates that Am-241 is not migrating in the SDA vadose zone at measurable concentrations at those particular monitoring locations, nor has it contaminated the aquifer beneath RWMC. Historically, extensive analytical evidence shows that Am-241 is not a widespread problem in either the vadose zone or aquifer at RWMC. For example, in the past 30 years, over 900 Am-241 sample analyses were performed on RWMC aquifer samples. These analyses resulted in only 11 positive detections, which were associated with 10 separate aquifer monitoring wells.

Table 3-5 summarizes concentration ranges, detection frequencies, and MCL exceedances in FY 2005, and Table 3-6 summarizes concentration ranges, detection frequencies, and MCL exceedances since monitoring began in 1997.

Table 3-5. Detected concentration ranges, detection rates, and maximum concentration level exceedances of americium-241 in Fiscal Year 2005.

Sample Medium	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	0.0	0/33	0	None	NA	NA	NA
Vadose zone (35 to 140 ft)							
Soil moisture	0.0	0/39	0	None	NA	NA	NA
Vadose zone (140 to 250 ft)							
Soil moisture and perched water	0.0	0/36	0	None	NA	NA	NA
Vadose zone (>250 ft)							
Soil moisture	0.0	0/24	0	None	NA	NA	NA
Aquifer	0.0	0/35	0	None	NA	NA	NA
Aquifer field blanks	0.0	0/4	0	None	NA	NA	NA

Note: Some reported results could be false positives (see caveat in Section 3.1).

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., background concentrations and maximum contaminant levels).

Table 3-6. Detected concentration ranges, detection rates, and maximum concentration level exceedances of americium-241 in sampled media since 1997.

Sample Medium	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	3.2	6/188	0	None	0.30 ± 0.09	2.8 ± 0.7	9 ± 2
Vadose zone (35 to 140 ft)							
Soil moisture	3.8	6/156	0	None	0.8 ± 0.2	4.0 ± 0.9	6.0 ± 1.2
Vadose zone (140 to 250 ft)							
Soil moisture and perched water	0.7	1/135	1	IE4	NA	NA	30 ± 2
Vadose zone (>250 ft)							
Soil moisture	0.0	0/37	0	None	NA	NA	NA
Aquifer	1.7	10/596	0	None	0.026 ± 0.008	0.55 ± 0.07	1.97 ± 0.13
Aquifer field blanks	2.2	1/46	0	None	NA	NA	0.031 ± 0.009

Note: Some reported results could be false positives (see caveat in Section 3.1).

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., background concentrations and maximum contaminant levels).

3.2 Carbon-14

Carbon-14 is a radioisotope generated by nuclear operations as an activation product. It decays by emission of beta particles and has a half-life of 5,715 years. Carbon-14 also occurs naturally with low abundance in the environment.

CAVEAT: *Concentrations of C-14 measured in soil-moisture samples may not be representative of actual concentrations in the vadose zone because the process of sampling soil moisture (i.e., vacuum) may cause a significant portion of C-14 to volatilize from the water sample. Therefore, measured concentrations reported in the succeeding sections may be low.*

This section presents results from analyses of vadose zone soil-moisture samples, vapor samples, and the aquifer. Available C-14 monitoring data for all media are summarized, and sampling data are evaluated against comparison concentrations in Table 2-2.

3.2.1 Buried Waste Inventory

Approximately 647 Ci of C-14 was buried in the SDA through 1999, and an additional 84.6 Ci is projected to be added by 2009, for a total of 731 Ci. Most C-14 inventory in the SDA is contained in activated steel. Some disposal inventory is in the form of reactor core components, including beryllium reflector blocks and end pieces from fuel assemblies. Most remaining activity is in ion-exchange resin. Typical C-14-bearing waste was buried in soil vault rows (SVRs) or trenches in the early years of operation (Holdren et al. 2006).

3.2.2 Vadose Zone

This section discusses historical and FY 2005 distributions of C-14 in vadose zone soil-moisture, perched water, and vapor samples at shallow-, intermediate-, and deep-depth intervals.

3.2.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 38 analyses for C-14 were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, resulting in two positive detections. Table 3-7 lists detected concentrations along with comparison values. The detection at location R1936:DL70 appears to be a one-time event because all subsequent samples from this lysimeter have been nondetections. The February 2005 detection at location W05:L24 is also a one-time occurrence because it was the first time this lysimeter yielded enough water to analyze for C-14. Without previous or subsequent data, no conclusions can be made about the presence or absence of C-14 at this location. Monitoring of the well will continue. Section 3.2.4 presents these data along with figures showing monitoring locations where detections occurred in FY 2005.

Since 1997, 143 analyses for C-14 were performed on shallow-depth lysimeter samples, resulting in 12 positive detections ranging in concentration from 11 to 4,350 pCi/L. Table 3-8 provides historical data for C-14 in shallow vadose zone samples since routine monitoring began in 1997. Section 3.2.4 summarizes concentration ranges, detection rates, and MCL exceedances since 1997. Historically, as shown in Table 3-8, detections are sporadic, with no apparent trends or spatial pattern.

Table 3-7. Carbon-14 detections in shallow-depth (0 to 35 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level (pCi/L) ^a
Carbon-14	11/17/04	R1936:DL70	30	39 ± 9	49	2,000
	02/02/05	W05:L24	15.9	316 ± 17	46	

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Table 3-8. Carbon-14 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Carbon-14 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS-1 : L41	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																				
	2																				
	3							16					11								
	4							19													
1998	1																				
	2																				
	3							22													
	4																				
1999	1																				
	2																				
	3																				
	4																				
2000	1																				
	2																				
	3																				
	4																				
2001	1																				
	2																				
	3																				
	4																				
2002	1																				
	2																				
	3																				
	4																				

Table 3-8. (continued).

Carbon-14 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS-1 : L41	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2003	1																				
	2																				
	3																				
	4																				
2004	1					4,350															
	2																				
	3						82*														
	4																				
2005	1									39											
	2										316										
	3																				
	4																				
Note: The highest result is reported for duplicate samples or reanalysis.																					
* = indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																					
For comparison, the maximum contaminant level = 2,000 pCi/L.																					
		Analysis was performed, but C-14 was not detected.																			
		C-14 was detected (pCi/L). Reported concentrations could be biased low (see caveat in Section 3.2).																			
		Well removed to accommodate grouting operations.																			

3.2.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 46 analyses for C-14 were performed on soil-moisture samples collected from 16 lysimeters near RWMC, resulting in nine positive detections. Table 3-9 lists detected concentrations along with comparison values. The detection rate is 19.6%, which is significantly higher than previous years (i.e., 10.1%). Positive results did not exceed the MCL of 2,000 pCi/L, nor are concentration trends associated with any of the monitoring wells. Section 3.2.4 provides these data along with figures showing monitoring locations where detections occurred in FY 2005.

Table 3-9. Carbon-14 detections in intermediate-depth (35 to 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Carbon-14	11/17/04	O-2:DL20	106	107 ± 9	17	2,000
	11/17/04	R1935:DL60	96	152 ± 10	19	
	11/17/04	R1936:DL68	113	36 ± 9	17	
	02/02/05	I-4S:DL15	97	40 ± 12	37	
	02/07/05	I-2S:DL11	92	38 ± 11	36	
	05/24/05	I-3S:DL13	93	43 ± 12	37	
	05/25/05	I-4S:DL15	97	54 ± 17	53	
	05/26/05	O-2:DL20	106	60 ± 14	45	
	08/09/05	I-3S:DL13	93	55 ± 9 ^b	28	

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

b. Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the C-14 result because C-14 was statistically detected in the method blank. Consequences to sample results are minimal. The data are usable, but should only be used as an estimated quantity. A statistical detection is not a positive detection; it is defined as a result greater than two times, but less than three times, its reported 1σ uncertainty and less than its minimum detectable concentration.

Such an increase in the number of detections in this depth interval in FY 2005 may or may not suggest C-14 migration in the SDA and may be associated with in situ grouting operations in FY 2004. Continuation of soil-moisture and vapor monitoring in the vadose zone may provide answers to the increased number of detections.

Since 1997, 109 analyses for C-14 were performed on intermediate-depth lysimeter samples, resulting in 11 positive detections ranging in concentration from 36 to 152 pCi/L. Table 3-10 presents historical data for C-14 in intermediate-depth vadose zone samples since routine monitoring began in 1997. Section 3.2.4 summarizes concentration ranges, detection frequencies, and MCL exceedances since 1997.

Table 3-10. Carbon-14 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Carbon-14 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																		
	2																		
	3																		
	4																		
1998	1																		
	2																		
	3																		
	4																		
1999	1																		
	2																		
	3																		
	4																		
2000	1																		
	2																		
	3																		
	4																		
2001	1																		
	2																		
	3																		
	4																		
2002	1																		
	2																		
	3																		
	4																		

Table 3-10. (continued).

Carbon-14 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2003	1																		
	2																		
	3																		
	4					46													
2004	1																		
	2																		
	3						39*												
	4																		
2005	1									107					152	36			
	2					38		40											
	3						43	54		60									
	4						55*												
Note: The highest result is reported for duplicate samples or reanalysis.																			
* = indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																			
For comparison, the maximum contaminant level = 2,000 pCi/L.																			
	Analysis was performed for C-14, but none was detected.																		
	C-14 was detected (pCi/L). Reported concentrations could be biased low (see caveat in Section 3.2).																		

3.2.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 65 analyses for C-14 in samples of perched water and soil moisture from 25 monitoring locations near RWMC resulted in 11 positive detections. Table 3-11 lists detected concentrations along with comparison values. Soil-moisture samples were obtained from as deep as 141 m (463 ft), and three of the 11 detections were observed deeper than 250 ft. As noted in the intermediate-depth interval (i.e., 35 to 140 ft), the detection rate in deep regions of the vadose zone also has increased from historical rates near 12 to 17%. Such an increase may or may not be suggestive of C-14 migration in the SDA because many of the detections also occurred in samples collected from background wells outside the SDA. Positive results did not exceed the MCL of 2,000 pCi/L, and no concentration trends are associated with any of the monitoring wells. Section 3.2.4 presents these data, along with figures showing monitoring locations where detections occurred in FY 2005.

Table 3-11. Carbon-14 detections in deep (greater than 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Carbon-14	11/16/04	IE7:DL35	231	96 ± 12	37	2,000
	11/16/04	DE7:DL37	413	74 ± 11	36	
	11/17/04	R1935:DL52	383	51 ± 9	17	
	11/17/04	R1935:DL54	335.5	84 ± 9	17	
	11/17/04	R1935:DL57	236	62 ± 9	18	
	11/17/04	R1935:DL58	217.5	92 ± 9	17	
	11/17/04	R1936:DL67	143	73 ± 9	17	
	11/17/04	S1898:DL40	225	133 ± 9	17	
	02/07/05	S1898:DL40	225	56 ± 17	54	
	02/08/05	USGS-092	214	38 ± 12	37	
	08/08/05	IE8:DL38	224	56 ± 15 ^b	49	

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

b. Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the C-14 result because C-14 was statistically detected in the method blank. Consequences to sample results are minimal. The data are usable, but should only be used as an estimated quantity. A statistical detection is not a positive detection; it is defined as a result greater than two times, but less than three times, its reported 1σ uncertainty and less than its minimum detectable concentration.

Since 1997, 148 analyses for C-14 were performed on samples from deep lysimeters, with 18 positive detections ranging in concentration from 12 to 185 pCi/L. Table 3-12 presents historical data for C-14 in deep vadose zone samples since routine monitoring began in 1997. Concentration ranges, detection frequencies, and MCL exceedances since 1997 are summarized in Section 3.2.4

Table 3-12. Carbon-14 detections since 1997 in deep (greater than 140 ft) lysimeters.

Carbon-14 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																																		
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL61	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	S1898: DL40	USGS-092	
1997	1																																	
	2																																	
	3																																12	
	4																																13	
1998	1																																	
	2	20																															20	
	3																																	
	4																																	
1999	1																																	
	2																																	
	3																																	
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2000	1																																	
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2002	1																																	
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	3																																	
	4																																	
2003	1																																	
	2																																	
	3																																	
	4																																	
2004	1																																	
	2																																	
	3					185*																												
	4																																	
2005	1				74								96								51	84			62	92				73	133			
	2																														56	38		
	3																																	
	4													56*																				
Note: The highest result is reported for duplicate samples or reanalysis.																																		
* = indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.																																		
For comparison, maximum contaminant level = 2,000 pCi/L.																																		
	Analysis was performed for C-14, but none was detected.																																	
	C-14 was detected (pCi/L). Reported concentrations could be biased low (see caveat in Section 3.2).																																	

3.2.3 Soil-Gas Monitoring near SVR 12 and SVR 20

Activated steel and beryllium contain a large fraction of the total SDA inventory of C-14. In summer 2004, activated beryllium disposals were grouted to suppress the relatively rapid corrosion-driven release of C-14, and the surface soil at SVR 12 was recontoured for better drainage. In FY 2005, soil-gas samples were collected from vapor ports in the activated stainless steel study area (i.e., SVR 12), and from newly installed vapor ports at the activated beryllium study area (i.e., SVR 20). Figure 3-1 illustrates sampling locations near SVR 12 and SVR 20. Soil-gas samples typically are analyzed for C-14 volumetric concentration and carbon dioxide concentration, and C-14 specific activity (i.e., C-14 activity per unit mass of carbon in carbon dioxide, or specific activity) is calculated from the results of these two measurements. Carbon-14 specific activity is a measure of the degree of contamination of environmental carbon (predominantly the inorganic form in this case) relative to background conditions. Carbon dioxide concentration measurements are used to confirm that samples may be analyzed using the routine method and indicate the relative potential for volatilization of C-14 from solid or liquid phases.

In FY 2005, only the SVR-12-3 monitoring location was functional because the other SVR 12 monitoring locations were removed to facilitate grading. Location SVR-12-3 contains three vapor ports at depths ranging from 0.94 to 3.8 m (3.1 to 12.5 ft). The specific activity and volumetric concentrations of C-14 measured in soil gas in FY 2005 were significantly above background levels (see Table 3-13), and the specific activity generally appears to have increased in FY 2005 (see Table 3-14 and Figure 3-2). As shown in Table 3-13, the increased specific activity in FY 2005 is due to relatively low carbon dioxide concentrations and relatively high volumetric activity. More sampling and analysis is needed to determine whether a long-term trend is developing.

Original vapor sampling ports at SVR 20 (particularly those in the GSP-1 well) were located very near activated beryllium where the specific activity of C-14 in soil gas was quite high. The original ports were removed in summer 2004 to facilitate grouting operations; the ports were replaced with two new monitoring wells in August and November 2004. The new wells (i.e., RWMC-2022 and RWMC-2023) each contain four vapor ports at depths ranging from 1.2 to 5.9 m (3.9 to 19.4 ft). In FY 005, specific activities measured in samples from RWMC-2022 and RWMC-2023 also were greater than background, but to a lesser degree than in the original sampling locations (see Table 3-15). However, results from the new wells are not directly comparable to most of previous measurements (see Table 3-16) because the new sampling ports are located much farther from the beryllium blocks than most of the original ports (see Section 3.2.3.2). Besides being above background levels, the specific activity at both RWMC-2002 and RWMC-2023 varies consistently between monitoring depths within the same well (see Figure 3-3). Fiscal Year 2005 data provide a baseline for future comparisons.

3.2.3.1 Disposals and Historical Monitoring of Carbon-14 at SVR 12. Soil Vault Row 12 contains large amounts of C-14 from many disposals of what is believed to be activated stainless steel. Information gathered through conversations with past and present INL staff (Salomon 2004) indicates that these disposals are probably highly irradiated stainless steel end pieces removed from Experimental Breeder Reactor II spent fuel elements before uncontained (i.e., placed in baskets, not sealed) disposal at RWMC. Ten shipments of uncontained end pieces were buried in SVR 12. Soil concentrations measured near this waste are considered indicative of the rate of C-14 release from activated steel, presumably by corrosion. All C-14 in this area is assumed to have been released from activated stainless steel because the nearest recorded activated beryllium disposal is approximately 64 m (210 ft) from the vapor ports in SVR 12. Three clusters of three Type B probes with vapor ports were installed at SVR 12 in 2001 (see Figure 3-1), and the initial sampling was conducted in 2002. Samples were collected from all ports from 2002 until early summer 2004 when all but one of the clusters (i.e., SVR-12-3-VP1, -VP-2, and -VP-3) were removed from SVR 12 to facilitate grading operations. Sampling for C-14 from the remaining ports resumed in September 2004.

Since 2001, samples have been collected quarterly from functioning vapor ports at SVR 12 and SVR20, except for the period in summer 2004 when beryllium grouting operations precluded routine sampling. Table 3-14 presents C-14 specific activity for the Type B vapor probes remaining at SVR 12. Results for C-14 analyses indicate that C-14 specific activity in SVR 12 is regularly two to three orders of magnitude above the typical background level (i.e., 6.5 pCi/g carbon), and that the volumetric concentration is relatively stable, as compared with the C-14 specific activity. There appears to be little correlation between fluctuations in carbon dioxide concentration and C-14 volumetric concentration (see Table 3-12). Increased specific activity observed in the October 2005 samples from SVR 12 is a result of both the relatively low carbon dioxide concentration measured in the sample and the relatively high volumetric activity (see Table 3-13). Figure 3-4 shows the concentration history since 2001 and a notable increase in FY 2005. Tritium concentrations in soil gas near SVR 12 were previously measured and determined to be less than 600 pCi/L and most likely less than 100 pCi/L (near local background levels). The absence of tritium in the soil gas provides additional confidence that C-14 originates from the activated stainless steel in SVR 12 rather than a more distant activated beryllium disposal.

3.2.3.2 Disposals and Historical Monitoring of Carbon-14 at SVR 20. In 1993, six beryllium reflector blocks from Core 3 of the Advanced Test Reactor were buried in an auger hole in SVR 20. The blocks contained an estimated total of 12 Ci C-14 at time of disposal (Sebo et al. 2005), as well as a large tritium inventory. In 1994, suction lysimeters, thermistors, and vapor ports were placed adjacent to the auger hole between 2.7 and 6.2 m (8.9 and 20.3 ft) below grade, and an access tube for neutron soil-moisture measurement was installed (Ritter and McElroy 1999). In 2001, Type B vapor probes and tensiometers (Myers et al. 2004) were placed approximately 5 m (16.4 ft) laterally from the auger hole and 5.4 m (17.7 ft) below grade to monitor lateral migration of C-14 and tritium. Carbon-14 sampling began in 1996 and was discontinued after March 2004 when grouting operations required removal of existing instrumentation. Sets of four vapor ports were installed in each of two new wells at SVR 20 in August and November 2004 to sample soil gas after grouting. Most data from these new wells are not directly comparable to the earlier data; the exception is discussed in the following subsection.

Specific activity of C-14 near activated beryllium at SVR 20 was measured in soil-gas samples collected from the GSP-1 ports and one of the Type B vapor probes. The GSP-1 gas sampling ports were located approximately 0.8 to 1 m (2.6 to 3.3 ft) from the centerline of the auger hole, and the SVR-20-IPV-5-VP3 soil gas sampling port was located 5.4 m (17.7 ft) deep, approximately 5 m (16.4 ft) from the centerline. Historical pregrouting results for soil-gas samples are summarized in Table 3-16 and illustrated in Figure 3-5. Samples were collected using caustic solutions in bottles before FY 2000 and in Tedlar bags after FY 2000. The methods give comparable results for specific activity, but bag sampling and analysis is simpler and allows measurement of total C-14 activity as well as carbon dioxide concentration. Based on the results through spring 2004, C-14 specific activity in soil gas from GSP-1, near the buried beryllium, increased by a factor of 5 to 10 between 1996 and 2002 and decreased by roughly a factor of 3 from 2002 to 2004. The C-14 specific activity is approximately a factor of three less at SVR20-IPV-5-VP3, based on samples from both ports taken in November 2001, August 2002, and December 2003. All instrumentation was removed from this area in March 2004 to prepare for beryllium block grouting.

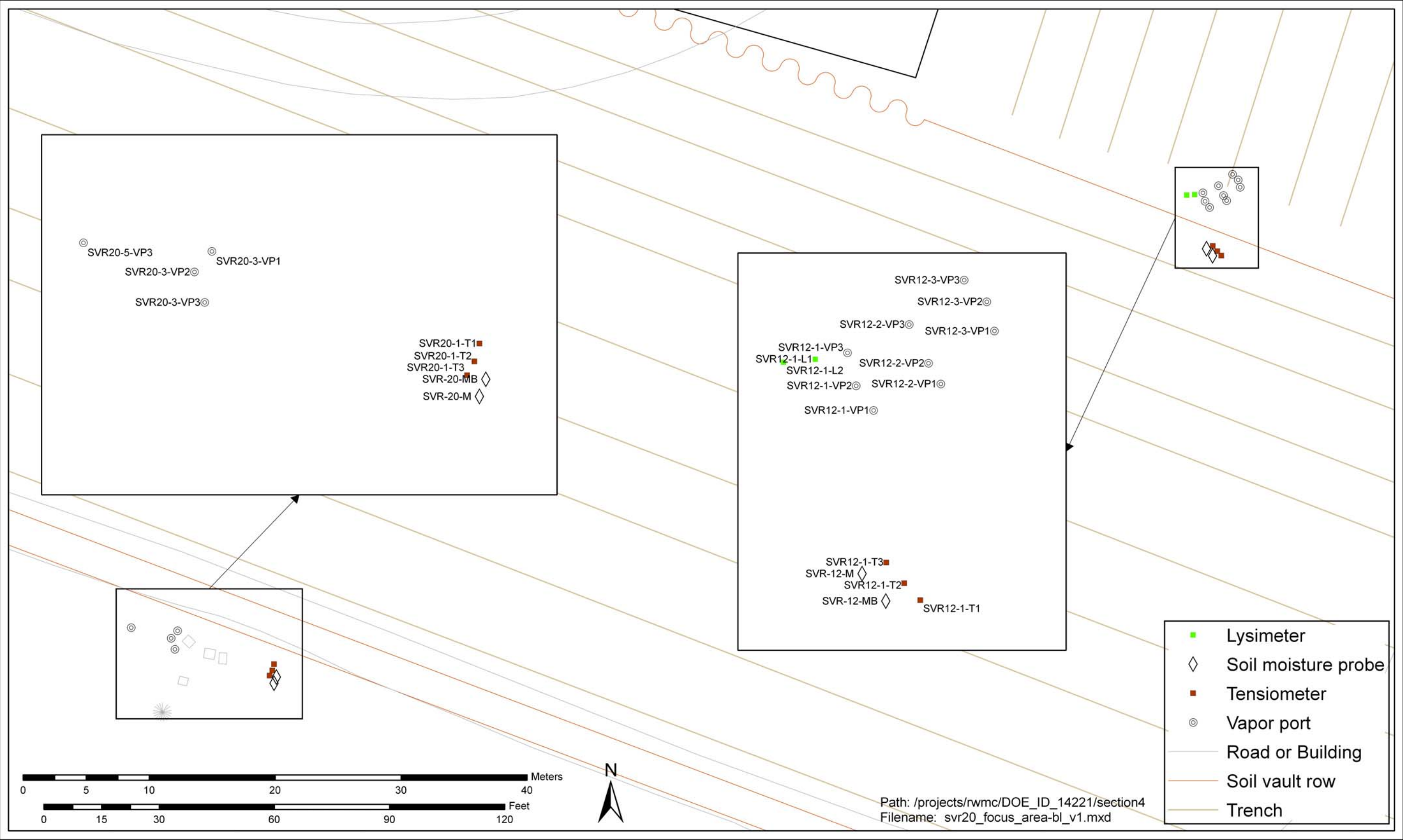


Figure 3-1. Vapor probes, tensiometers, lysimeters, and probes installed near or in SVR 12 and SVR 20.

Table 3-13. Specific and volumetric activities of carbon-14 and carbon dioxide concentrations from vapor probes at monitoring Well SVR-12-3 in Fiscal Year 2005.

Date	Well SVR-12-3								
	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3
	Specific Activity (pCi [C-14]/g [carbon])			Volumetric Activity (nCi [C-14]/L)			Carbon Dioxide Concentration (ppmv)		
11/30/04	1,860	1,070	2,580	1.05	1.64	0.94	1,580	4,660	1,020
02/21/05	<MDC	970	—	<MDC	1.63	—	—	4,630	—
05/31/05	<MDC	2,180	<MDC	<MDC	2.34	<MDC	1,070	3,400	2,510
08/23/05	20,370	3,760	5,830	7.65	4.37	5.14	1,070	3,400	2,510

Note: The typical background specific activity in atmospheric carbon dioxide is approximately 6.5 pCi [C-14]/g [carbon].

MDC = minimum detectable concentration

Table 3-14. Specific activity of carbon-14 from vapor probes at SVR 12 before and after grouting.

Date	SVR-12-1 ^a			SVR-12-2 ^a			SVR-12-3 ^a		
	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3
12/03/01	3,300	3,300	8,400	2,700	3,500	—	2,900	3,000	8,200
02/20/02	2,100	450	—	1,400	—	—	2,000	1,500	16,000
05/23/02	990	990	2,800	1,400	840	630	1,200	1,600	370
08/13/02	1,200	1,200	1,600	1,300	1,000	380	2,200	1,200	480
08/23/02	—	—	—	—	—	—	—	—	—
11/13/02	710	560	<MDC ^b	1,500	590	<MDC ^b	1,100	680	<MDC ^b
02/03/03	880	680	<MDC ^b	970	—	480	1,100	680	<MDC ^b
05/15/03	710	480	230	820	550	280	480	680	110
03/30/04	1,100	800	385	1,550	570	150	890	1,100	670
11/30/04	OOS	OOS	OOS	OOS	OOS	OOS	1,860	1,070	2,580
02/21/05	OOS	OOS	OOS	OOS	OOS	OOS	<MDC ^b	970	—
05/31/05	OOS	OOS	OOS	OOS	OOS	OOS	<MDC ^b	2,180	<MDC ^b
08/23/05	OOS	OOS	OOS	OOS	OOS	OOS	20,370	3,760	5,830

Note: Typical background specific activity in atmospheric carbon dioxide is approximately 6.5 pCi [C-14]/g [carbon].

a. pCi [C-14]/g [carbon].

b. Relative uncertainty is greater than 33%. Relative uncertainty of most other results is typically 5 to 10%.

MDC = minimum detectable concentration

OOS = out of service

— = no sample was taken on that date

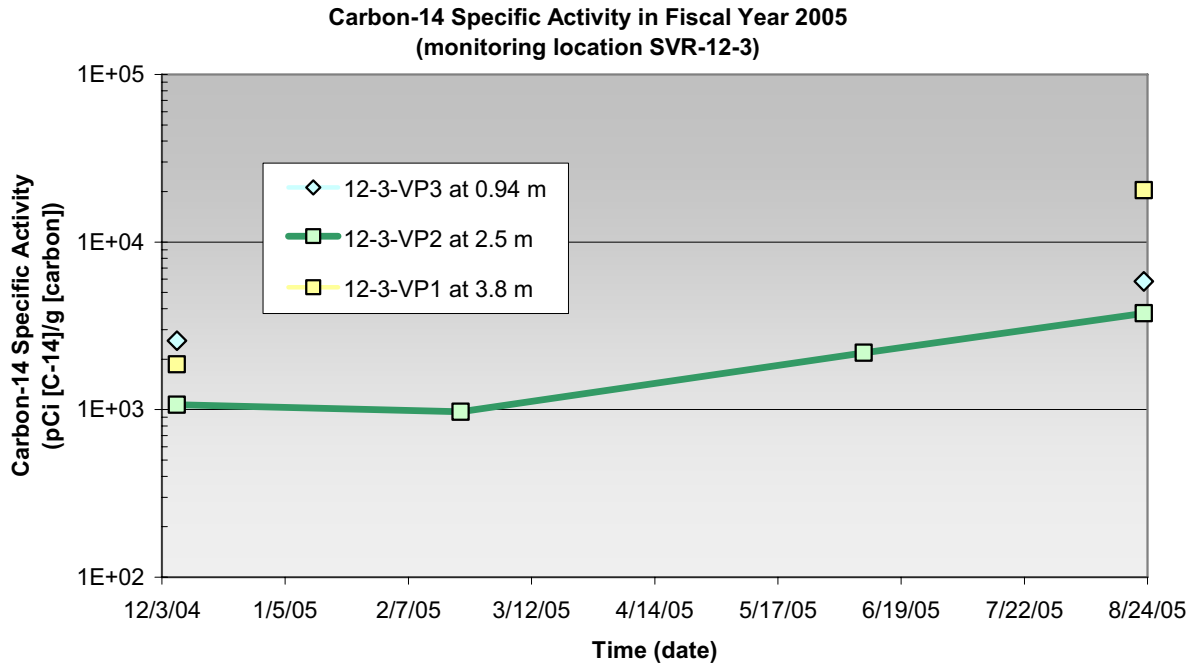


Figure 3-2. Specific activity of carbon-14 at SVR-12-3 in Fiscal Year 2005.

Table 3-15. Summary of carbon-14 specific activity in carbon dioxide in soil-gas samples collected from probes at SVR 20 in Fiscal Year 2005.

Date	RWMC-2022 ^a				RWMC-2023 ^a			
	Depth (m)				Depth (m)			
	1.2	2.7	4.6	5.9	1.2	2.7	4.6	5.6
12/7/2004	5.17E+04	4.44E+04	4.30E+04	4.57E+04	—	—	—	—
2/21/2005	4.71E+04	3.86E+04	—	3.11E+04	—	—	—	—
6/9/2005	4.85E+04	4.42E+04	4.09E+04	3.92E+04	1.79E+04	2.05E+04	2.32E+04	2.82E+04
8/23/2005	1.33E+05	1.12E+05	4.96E+04	4.35E+04	2.21E+04	2.27E+04	2.73E+04	—

a. pCi [C-14]/g [carbon].

Table 3-16. Summary of carbon-14 specific activity in carbon dioxide from soil-gas samples collected at SVR 20 before grouting.

Date	GSP-1 ^a			SVR 20-IPV-5-VP3 ^a
	Depth (m)			Depth (m)
	2.7	4.5	6.2	5.4
06/05/96	1.7E+04	—	2.3E+04	—
07/02/96	—	3.4E+04	2.5E+04	—
12/12/96	1.3E+05	4.2E+04	3.3E+04	—
11/12/97	4.4E+04	2.0E+04	1.2E+04	—
11/15/01	3.6E+05	1.6E+05	2.4E+05	8.3E+04
02/20/02	—	—	—	2.8E+04
05/02/02	1.7E+05	1.4E+05	1.3E+05	—
05/23/02	—	—	—	3.1E+04
08/23/02	1.3E+05	1.3E+05	1.4E+05	3.7E+04
11/13/02	—	—	—	2.4E+04
11/05/03	1.1E+05	1.4E+05	1.6E+05	4.1E+04
03/30/04	5.8E+04	6.4E+04	9.5E+04	—

Note: Typical background levels are approximately 6.5 pCi [C-14]/g [carbon].

a. pCi [C-14]/g [carbon].

— = no sample was taken on that date

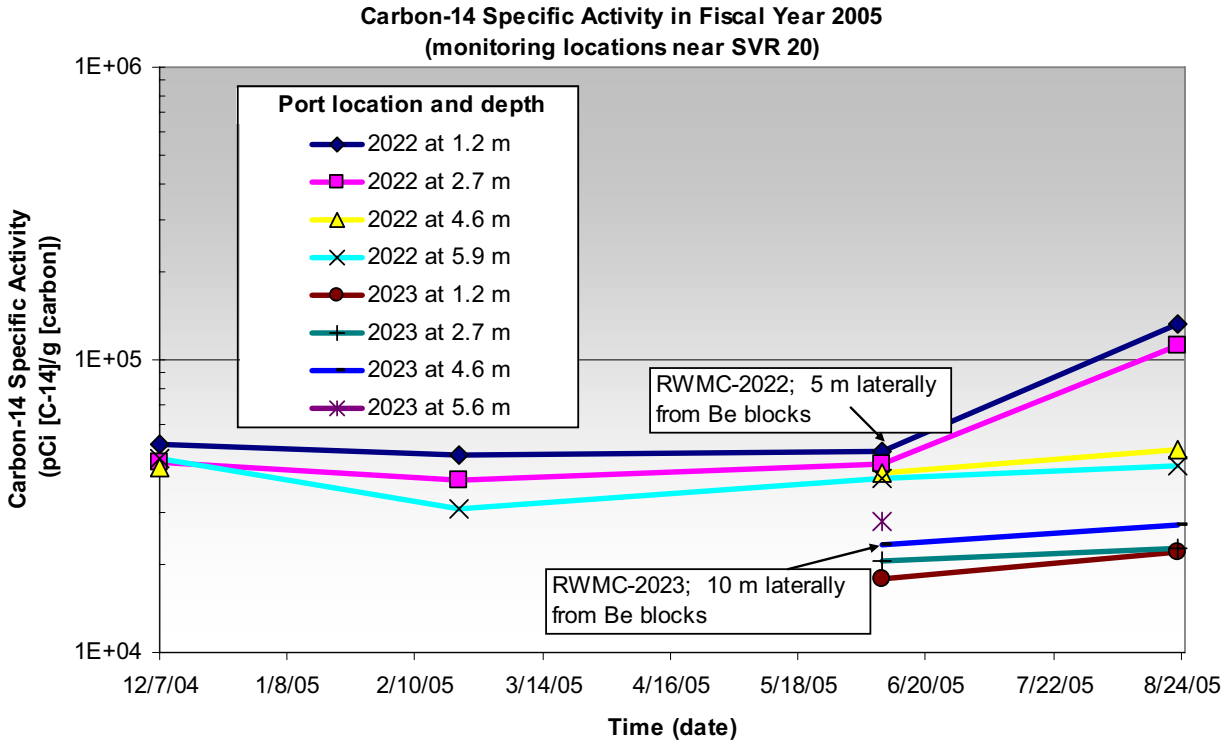


Figure 3-3. Specific activity of carbon-14 near SRV 20 in Fiscal Year 2005.

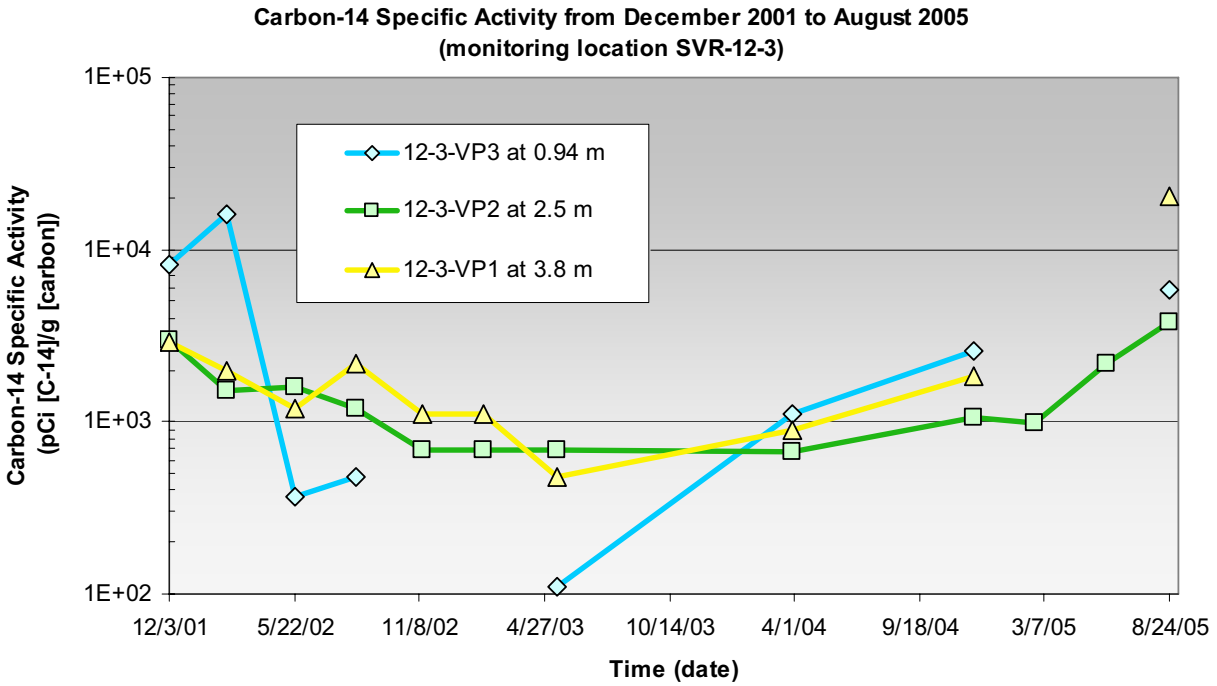


Figure 3-4. Specific activity of carbon-14 at SVR-12-3 since monitoring began in December 2001.

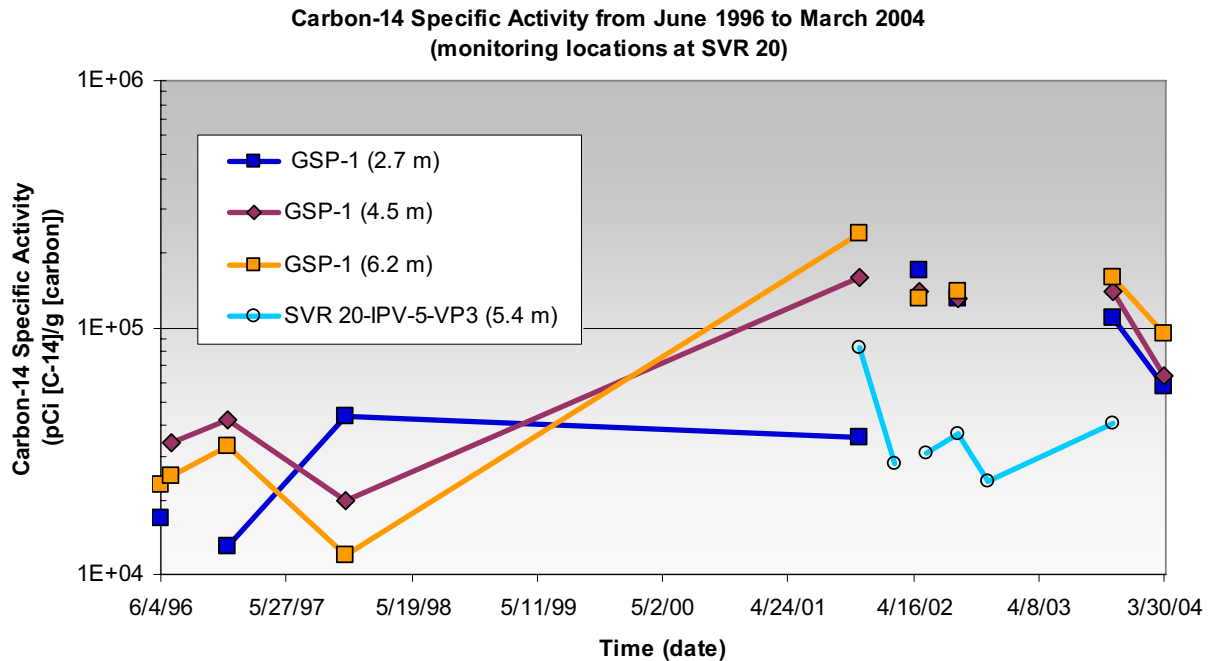


Figure 3-5. Specific activity of carbon-14 at SVR 20 since monitoring began in June 1996.

3.2.3.3 Post-Grout Monitoring for Carbon-14 at SVR 12 and SVR 20. Sets of four soil-gas sampling ports were installed in each of two new wells (i.e., RWMC-2022 and RWMC-2023) to monitor C-14 and tritium in SVR 20 after grout injection. The new wells were constructed similarly to the GSP-1 well. Wells RWMC-2022 and RWMC-2023 are located 5.8 and 8.8 m (19 and 29 ft), respectively, from the activated beryllium buried in SVR 20. Ports in each well open at depths of 1.2, 2.7, and 4 m (4, 9, and 13 ft). Because of differences in the depth to the basalt layer, the bottom port on Well RWMC 2022 is located 5.9 m (19.5 ft) deep; the bottom port on Well RWMC-2023 is located 5.6 m (18.5 ft) deep. The new ports were installed farther from the buried beryllium to avoid the grout containment unit and grout-affected soil. Initial samples were taken from Wells RWMC-2022 and RWMC-2023 in September and December 2004, respectively. Because of the large difference in port locations, data from the new vapor ports are presented separately from those obtained from the abandoned ports. Table 3-15 summarizes first-year monitoring results. The specific activity of C-14 is significantly above background levels and varies at all depths and distances by an approximate factor of 3 over the course of 1 year. Specific activity of C-14 is greatest at the 1.2-m (4-ft) port on Well RWMC-2022, which is closest to the beryllium disposal and nearest to the soil surface. Fiscal Year 2005 data represent a baseline that will be used for future comparisons. Monitoring for several years will be required to determine what effects grouting has on C-14 release into the soil, but no trend can be detected using the current, limited data set from these ports.

One comparison may be made between past and present data sets: the Type B vapor port SVR20-IPV-5-VP3 and the new vapor port installed 5.9 m (19.4 ft) deep in RWMC-2022. Inlets of both ports were positioned 5 to 6 m (16.4 to 19.7 ft) below grade and were installed 5 to 6 m (16.4 to 19.7 ft) laterally from the beryllium disposal. The major difference between these two vapor ports is that the abandoned Type B vapor port was located west of the disposal, whereas the new vapor port bundle is located east of the disposal. However, assuming that lateral gas transport in the soil adjacent to the disposal site is equal in all directions, results from these two ports should be comparable (Nalla 2004).

Figure 3-6 shows results from SVR20-IPV-5-VP3 and RWMC-2022. Specific activities of C-14 in the initial RWMC-2022 samples are within the range previously observed at SVR20-IPV-5-VP3. This suggests that any effects of grouting on the specific activity of C-14 at this location have yet to be detected at this distance from the beryllium disposal.

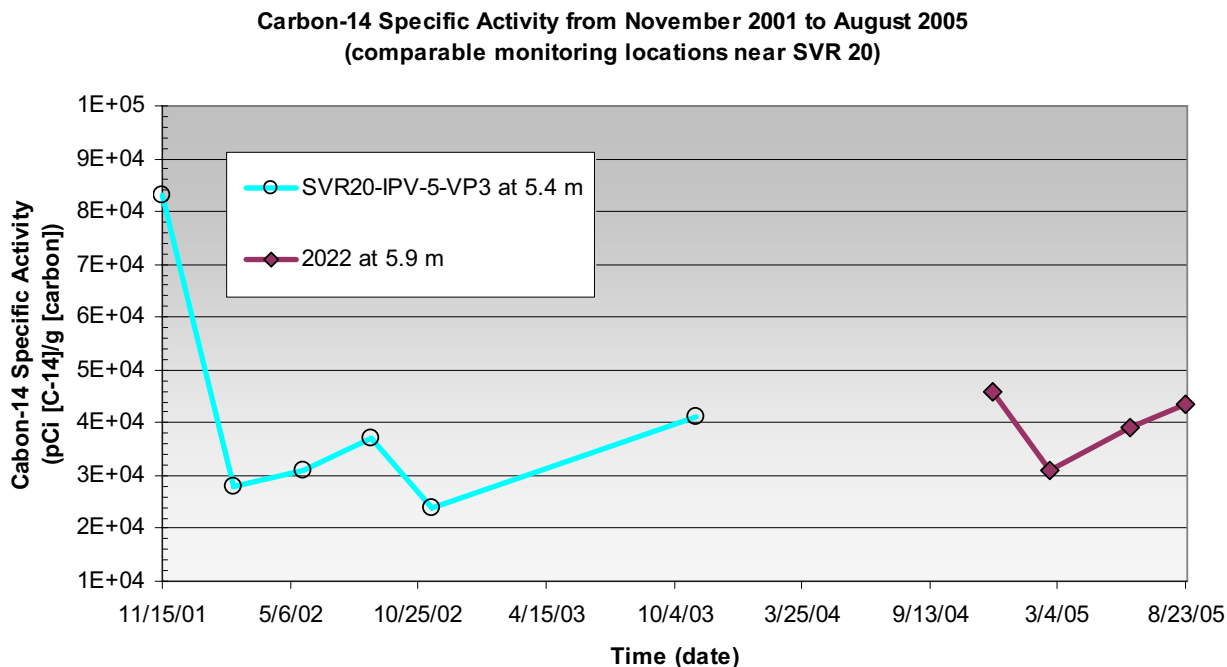


Figure 3-6. Specific activity of carbon-14 at comparable locations near SVR 20 since monitoring began in 2001.

3.2.3.4 Summary of Soil-Gas Monitoring for Carbon-14 at SVR 12 and SVR 20. The following list summarizes soil-gas monitoring for C-14 at SVR 12 and SVR 20:

- One year after grouting, the specific activity of C-14 at SVR 20 remains above background levels.
- Carbon-14 data from the SVR20-IPV-5-VP3 (removed during summer 2004) and RWMC-2022 ports were expected to be comparable, based on the similar depth and lateral displacement from the auger hole. Preliminary sampling results in FY 2005 are consistent with this expectation and suggest no significant change in C-14 specific activity.
- Carbon-14 concentrations in the activated steel study area did not decrease after grouting nearby beryllium blocks, suggesting that C-14 concentrations in the activated steel study area are primarily from the activated steel rather than the more distant beryllium.
- Carbon-14 specific activity near the activated steel in SVR 12 is about two orders of magnitude greater than background but still one to two orders of magnitude less than that observed on the new sampling ports on SVR 20.

- On SVR 20, specific activity of C-14 decreases with increasing depth, suggesting migration upward into the atmosphere rather than migration downward toward the aquifer. This observation is supported by observations made in the meso-scale column work of Fox et al. (2004).

3.2.4 Aquifer

In FY 2005, 34 analyses for C-14 were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, resulting in no positive detections.

Since 1997, 399 analyses for C-14 were performed on aquifer samples, with 26 positive detections ranging in concentration from 1.8 to 42 pCi/L. Table 3-17 presents historical data and the distribution of C-14 detections in aquifer samples since 1997. Concentration ranges, detection rates, and MCL exceedances since 1997 are summarized in Section 3.2.5. Historical results for aquifer samples show sporadic detections of C-14, but no evident trends or spatial patterns. The number of C-14 detections in monitoring wells upgradient of RWMC (i.e., M3S, M7S, M12S, and M13S) is slightly higher than other well locations and may be attributable to past discharge practices at upgradient facilities (see further discussion in Sections 3.4.1, 3.4.3, 3.13.2.2, and 3.13.2.3). Concentrations of C-14 are two to three orders of magnitude less than the MCL.

Table 3-17. Carbon-14 detections in aquifer monitoring wells since 1997.

Carbon-14 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	All A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4				3.0	6.7											
1999	1																
	2				4.4						4.9						
	3																
	4						11										
2000	1													5.3	1.8		
	2																
	3																
	4				2.1	3.2	4.0				2.8	3.3			2.2		
2001	1																
	2																
	3			2.8	2.9	3.3											4.5
	4									42							

Table 3-17. (continued).

Table 5-17 (continued)

Carbon-14 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	All A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
2002	1																
	2							4.5		7.5							
	3	3.1															
	4	7.1											3.5				
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis.																	
For comparison, maximum contaminant level = 2,000 pCi/L.																	
	Analysis was performed, but C-14 was not detected.																
	C-14 was detected (pCi/L).																
	Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.																

3.2.5 Summary of Carbon-14

Carbon-14 detections in vadose zone soil moisture at intermediate and deep monitoring intervals increased in FY 2005. Detection frequencies in these intervals increased to nearly 20% from historical rates of 10% in the 35 to 140-ft depth interval and 14% in the 140 to 250-ft depth interval. The detection rate at depths greater than 250 ft also increased; however, the increase was more subtle: from 8 to 13% (see Tables 3-18 and 3-19). Concentrations are low, and trends are not discernible at any location.

One year after grouting, C-14 detections near activated stainless and buried beryllium blocks remain above background and show no apparent decrease in activity. Because new sampling ports were installed near SVR 20, most pre- and post-grouting C-14 data are not directly comparable. However, data from the two sampling locations that are marginally comparable suggest no detectable changes in C-14 activity since grouting at SVR 20.

Of the aquifer samples collected and analyzed for C-14 from 1997 through FY 2005, 6.5% have positive detections; however, the detection frequency of C-14 in field blank samples for this same period is 3.6% (see Table 3-19), indicating that some aquifer detections either may be false positives.

Table 3-18 summarizes C-14 concentration ranges, detection frequencies, and MCL exceedances, and Figure 3-7 shows monitoring locations where C-14 was detected in FY 2005. Table 3-19 shows concentration ranges, detection frequencies, and MCL exceedances since monitoring began in 1997.

Table 3-18. Concentration ranges, detection frequencies, and maximum contaminant level exceedances of carbon-14 in Fiscal Year 2005.

Sample Medium	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations			
					Minimum	Mean	Maximum	Units
Vadose zone (0 to 35 ft)								
Soil moisture	5.3	2/38	0	None	NA	NA	NA	pCi/L
Soil gas (SVR 12)	72.7	8/11	8	SVR-12-3 (VP1, VP2, and VP3)	970	4,828	20,370	pCi[C-14]/g [carbon]
Soil gas (SVR 20)	100	22/22	22	R2022 (1.2, 2.7, 4.6, and 5.9m) R2023 (1.2, 2.7, 4.6, and 5.6m)	17,902	44,313	133,490	pCi[C-14]/g [carbon]
Vadose zone (35 to 140 ft)								
Soil moisture	19.6	9/46	0	None	36 ± 9	65 ± 11	152 ± 10	pCi/L
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	19.5	8/41	0	None	38 ± 12	76 ± 11	133 ± 9	pCi/L
Vadose zone (>250 ft)								
Soil moisture	12.5	3/24	0	None	51 ± 9	70 ± 10	84 ± 9	pCi/L
Aquifer	0.0	0/34	0	None	NA	NA	NA	pCi/L
Aquifer field blanks	0.0	1/1	0	None	NA	NA	NA	pCi/L

Note: Some reported results could be false positives (see caveat in Section 3.2).

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels).

Table 3-19. Concentration ranges, detection rates, and maximum contaminant level exceedances of carbon-14 in sampled media since monitoring began.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations			
					Minimum	Mean	Maximum	Units
Vadose zone (0 to 35 ft)								
Soil moisture	8.4	12/143	1	LYS-1:L41	11 ± 3	415 ± 16	4,350± 116	pCi/L
Soil gas (SVR 12) ^c	89.7	70/78	70	SVR-12-1, -12-2, and -12-3 (VP1, VP2, and VP3)	110	2,003	20,370	pCi[C-14]/g [carbon]
Soil gas (SVR 20) ^c	100	29/29	29	GSP-1 (VP1, VP2, VP3) SVR-20-IPV-5 (VP3)	13,000	81,600	240,000	pCi[C-14]/g [carbon]
Vadose zone (35 to 140 ft)								
Soil moisture	10.1	11/109	0	None	36 ± 9	61 ± 11	152 ± 10	pCi/L
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	13.5	15/111	0	None	12 ± 3	67 ± 11	185 ± 16 _J ^d	pCi/L
Vadose zone (>250 ft)								
Soil moisture	8.1	3/37	0	None	51 ± 9	70 ± 10	84 ± 9	pCi/L
Aquifer	6.5	26/399	0	None	1.8 ± 0.5	5.6 ± 0.8	42 ± 1	pCi/L
Aquifer field blanks	3.6	1/28	0	None	NA	NA	2.0 ± 0.5	pCi/L

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

c. Vapor results are compared to a C-14 background concentration of 6.5 pCi/g of carbon. Carbon is calculated from the amount of carbon dioxide in the sample.

d. Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the C-14 result because of analytical quality control anomalies. The results are questionable and should be used only as estimated quantities.

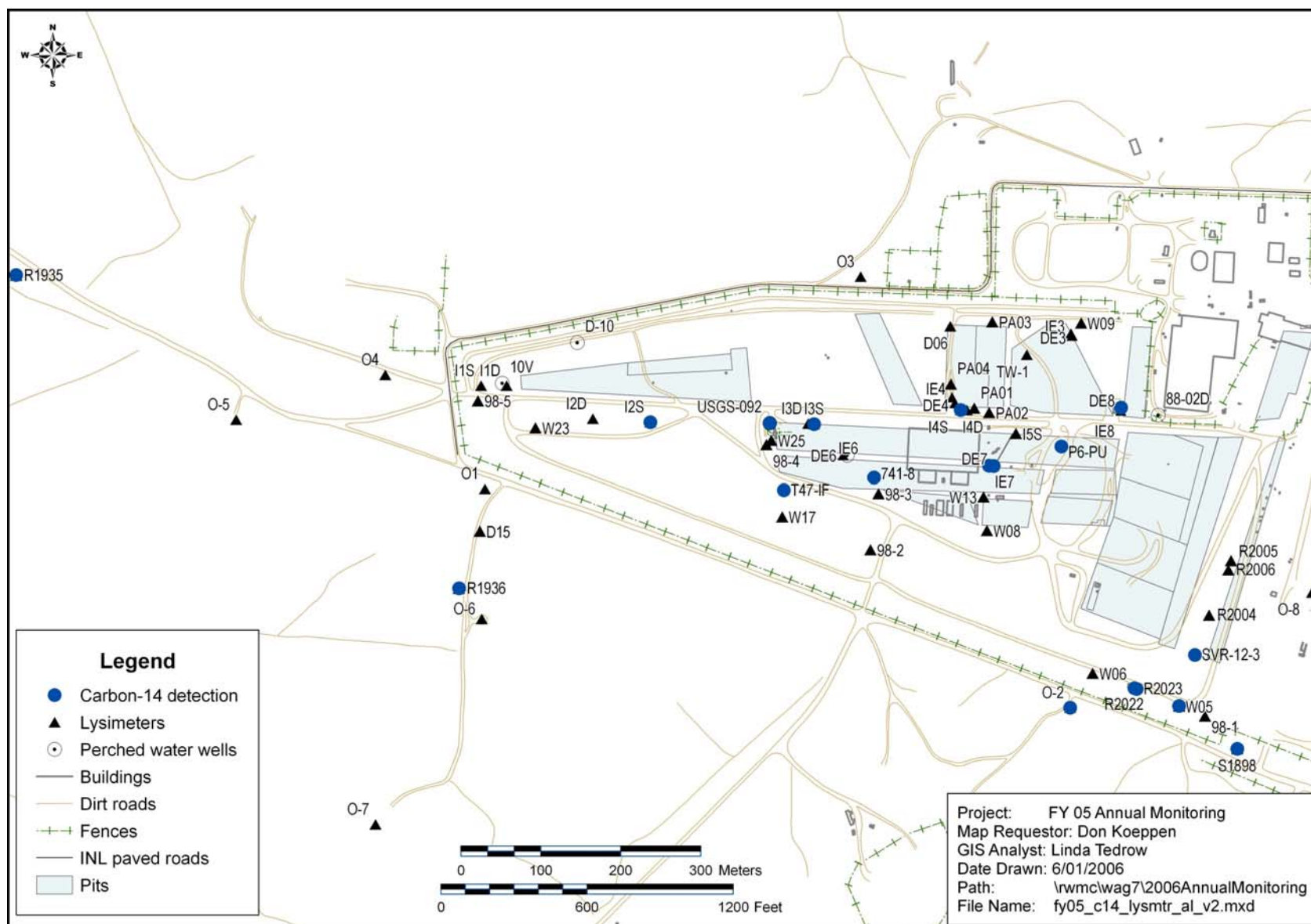


Figure 3-7. Carbon-14 detections in the Subsurface Disposal Area in Fiscal Year 2005.

3.3 Cesium-137

Cesium-137 is a fission product generated primarily by nuclear reactor operations and weapons testing. It decays by the emission of beta particles and gamma rays, has a 30-year half-life, and is ubiquitous globally in the environment at low levels because of historical atmospheric nuclear bomb testing.

Cesium-137 is rarely detected in samples from vadose zone cores, lysimeters, perched water, and aquifer monitoring wells. This section summarizes Cs-137 monitoring data for all media. Sampling data in this section are evaluated against comparison concentrations in Table 2-2.

3.3.1 Buried Waste Inventory

Approximately $1.72\text{E}+05$ Ci of Cs-137 was buried in the SDA (through 1999), and an additional $3.04\text{E}+02$ Ci is projected to be added by 2009, for a total of $1.73\text{E}+05$ Ci. The primary source of Cs-137 in the SDA is INL Site reactor operations waste and subassembly hardware (Holdren et al. 2006).

3.3.2 Vadose Zone

The following subsections discuss distribution of Cs-137 in vadose zone cores, soil moisture, and perched water in the various depth intervals.

3.3.2.1 Lysimeter Samples at Depths of 0 to 35 ft. Between November 2004 and August 2005, 35 Cs-137 analyses were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, with no positive detections.

Since 1997, Cs-137 was detected only once; therefore, a table of occurrences is not presented. The detected concentration of $1,760 \pm 136$ pCi/L occurred in September 2000, and Cs-137 has not been detected in shallow-depth lysimeters since that time. Because only one Cs-137 detection was occurred since 1997, a table presenting historical concentrations, concentration ranges, detection rates, and exceedances is not included.

3.3.2.2 Lysimeter Samples at Depths of 35 to 140 ft. Between November 2004 and August 2005, 44 Cs-137 analyses were performed on soil-moisture samples collected from 16 intermediate-depth lysimeters near RWMC, with no positive detections.

No Cs-137 has been detected in any lysimeters from this depth range since sample collection began in 1997; therefore, a table showing historical detections and nondetections, detection rates, or exceedances in the intermediate-depth vadose zone is not presented.

3.3.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 73 analyses for Cs-137 were performed on samples collected from 26 lysimeters and two perched water wells, yielding no positive detections.

Since routine monitoring began in 1997, Cs-137 was detected only once; therefore, a table of occurrences is not presented. The detection occurred in October 2003 at a concentration of 105 ± 12 pCi/L. No other detections have occurred since that time; therefore, a table presenting historical concentrations, concentration ranges, detection rates, and exceedances is not included.

3.3.3 Aquifer

In FY 2005, 35 analyses for Cs-137 were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, with no positive detections.

Since 1997, more than 400 Cs-137 analyses have been performed on samples collected from 16 aquifer monitoring wells, with three positive detections. Detections were one-time occurrences in Wells M7S, M12S, and M13S, with concentrations ranging from 3.9 to 7.8 pCi/L. None of the detections exceeded the MCL of 200 pCi/L. Because detections are so few, a table presenting historical concentrations, concentration ranges, detection rates, and exceedances is not included.

3.3.4 Summary of Cesium-137

Cesium-137 was not detected in any vadose zone soil-moisture, perched water, or aquifer samples in FY 2005.

3.4 Chlorine-36

Chlorine-36 is a radioisotope generated by nuclear reactor operations and weapons testing. In addition, cosmic rays interact with argon to produce extremely low concentrations of Cl-36 in the environment. It decays by the emission of beta particles and has a 301,000-year half-life.

This section summarizes available Cl-36 monitoring data for all sample media. Sampling data in this section are evaluated against comparison concentrations shown in Table 2-2.

3.4.1 Buried Waste Inventory

Approximately 1.12 Ci of Cl-36 was buried in the SDA through 1999, and an additional 0.538 Ci is projected to be added by 2009, for a total of 1.66 Ci (Holdren et al. 2006).

3.4.2 Vadose Zone

This section discusses historical and FY 2005 distributions of Cl-36 in vadose zone soil moisture and perched water in shallow-, intermediate-, and deep-depth intervals. Routine Cl-36 monitoring in the vadose zone did not begin until October 2002.

3.4.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 29 analyses for Cl-36 on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC resulted in one positive detection at location PA01:L15 (see Table 3-20). The detection is considerably less than the MCL of 700 pCi/L used for comparison. Chlorine-36 was not detected in location PA01:L15 during subsequent sampling events; however, it was detected in the August 2004 sampling round. Section 3.3.4 presents these data, along with figures showing monitoring locations where detections occurred in FY 2005.

Table 3-20. Chlorine-36 detections in shallow-depth (0 to 35 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Cl-36	11/15/04	PA01:L15	14.3	28 ± 8	28	700

a. The maximum contaminant level is from the "National Primary Drinking Water Standards" (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Since 2002, 72 analyses for Cl-36 were performed on shallow-depth lysimeter samples, with five positive detections ranging in concentration from 3.5 to 32.3 pCi/L. Table 3-21 presents historical data for Cl-36 in shallow vadose zone samples since routine monitoring of Cl-36 began in 2002. Section 3.3.4 summarizes concentration ranges, detection rates, and MCL exceedances since 2002. Historically, as shown in Table 3-21, detections are sporadic with no apparent trends or spatial pattern.

Table 3-21. Chlorine-36 detections in shallow-depth (0 to 35 ft) lysimeters since monitoring began in 2002.

Table 3-21: Chlorine-36 detections in shallow upper (0 to 35 ft) lysimeters since monitoring began in 2002.

Chlorine-36 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2002	1 to 4																			
2003	1			3.5										5.8			32*			
	2																			
	3																			
	4																			
2004	1																			
	2																			
	3																			
	4																			
2005	1																			
	2																			
	3																			
	4																			

Note: The highest result is reported for duplicate samples or reanalysis.
* = indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.
For comparison, maximum contaminant limit = 700 pCi/L.

	Analysis was performed, but Cl-36 was not detected.
	Cl-36 was detected (pCi/L.)

3.4.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 31 analyses for Cl-36 on soil-moisture samples collected from 13 intermediate-depth lysimeters near RWMC resulted in one positive detection at location I-2S:DL11 (see Table 3-22). The detections are considerably less than the MCL of 700 pCi/L used for comparison. Chlorine-36 was not detected at location I-2S:DL11 in previous or subsequent sampling events; therefore, its presence at this monitoring location is highly doubtful and will continue to be monitored. Section 3.3.4 presents these data, along with figures showing monitoring locations where detections occurred in FY 2005.

Table 3-22. Chlorine-36 detections in intermediate-depth (35 to 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Cl-36	11/15/04	I-2S:DL11	92	23 ± 6 _J ^b	22	700

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Since 2002, 98 analyses for Cl-36 were performed on intermediate-depth lysimeter samples, with four positive detections ranging in concentration from 5.6 to 31.6 pCi/L. Table 3-23 presents historical data and the occurrence of detections in intermediate-depth lysimeters since Cl-36 routine monitoring began. Section 3.3.4 summarizes concentration ranges, detection rates, and MCL exceedances since 2002. Historically, as shown in Table 3-23, detections are sporadic, and no apparent trends or spatial pattern are evident.

3.4.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 45 analyses for Cl-36 were performed on samples collected from 18 lysimeters and two perched water wells near RWMC, with no positive detections.

Since 2002, 107 analyses for Cl-36 were performed on samples from deep lysimeters, yielding one positive detection with a concentration of 8.7 pCi/L. Table 3-24 presents historical data and the occurrence of detections since Cl-36 monitoring began. Section 3.3.4 summarizes detection frequencies, concentration ranges, and MCL exceedances for Cl-36 in deep lysimeters and perched water wells since 2002.

3.4.3 Aquifer

In FY 2005, 35 analyses for Cl-36 were performed on aquifer samples collected from 15 monitoring wells near RWMC, with no positive detections.

Since 2001, 78 analyses for Cl-36 were performed on aquifer samples, with no positive detections. Table 3-25 presents historical data and detection occurrences in aquifer samples since Cl-36 monitoring began in 2001. Section 3.3.4 summarizes i.e., detection frequencies, concentration ranges, and MCL exceedances for Cl-36 since 2001.

3-44

Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2002	1 to 4																		
2003	1				5.6														
	2																		
	3																		
	4																		
2004	1																		
	2																		
	3		28		32														
	4																		
2005	1					23*													
	2																		
	3																		
	4																		

Note: The highest result is reported for duplicate samples or reanalysis.

* = indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.

For comparison, the maximum contaminant level = 700 pCi/L.

	Analysis was performed for Cl-36, but none was detected.
	Cl-36 was detected (pCi/L).

Table 3-24. Chlorine-36 detections in deep (greater than 140 ft) lysimeters and perched water wells.

Chlorine-36 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																																	
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL61	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	S1898: DL40	USGS-092
2002	1 to 4																																
2003	1																																8.7
	2																																
	3																																
	4																																
2004	1																																
	2																																
	3																																
	4																																
2005	1																																
	2																																
	3																																
	4																																
Note: The highest result is reported for duplicate samples or reanalysis.																																	
For comparison, the maximum contaminant level = 700 pCi/L.																																	
	Analysis was performed for Cl-36, but none was detected.																																
	Cl-36 was detected (pCi/L).																																

Table 3-25. Chlorine-36 detections in aquifer monitoring wells since 2001.

Chlorine-36 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	All A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS -127
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, maximum contaminant level = 700 pCi/L.																	
	Analysis was performed, but Cl-36 was not detected.																
	Cl-36 was detected (pCi/L).																
	Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.																

3.4.4 Summary of Chlorine-36

In FY 2005, two detections were associated with 136 sample analyses from samples taken near RWMC, one in the shallow-depth and one in the intermediate-depth interval of the vadose zone. Table 3-26 summarizes concentration ranges, detection frequencies, and exceedances. Figure 3-8 shows monitoring locations where Cl-36 was detected in FY 2005.

Table 3-27 presents historical concentration ranges and detection frequencies and shows that Cl-36 detections are rare and have been confined to the vadose zone between 3 and 31 m (10 and 101 ft) deep. Table 3-27 shows concentration ranges, detection frequencies, and MCL exceedances since aquifer monitoring began in 2001 and vadose zone monitoring began in 2002. Also, detection frequencies are highest in shallow regions of the vadose zone and lowest in deep regions. All positive results are significantly less than the MCL of 700 pCi/L.

Table 3-26. Concentration ranges, detection frequencies, and maximum contaminant level exceedances of chlorine-36 in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	3.4	1/29	0	None	NA	NA	28 ± 8
Vadose zone (35 to 140 ft)							
Soil moisture	3.2	1/31	0	None	NA	NA	23 ± 6
Vadose zone (140 to 250 ft)							
Soil moisture	0.0	0/23	0	None	NA	NA	NA
Vadose zone (>250 ft)							
Soil moisture	0.0	0/22	0	None	NA	NA	NA
Aquifer	0.0	0/35	0	None	NA	NA	NA
Aquifer field blanks	0.0	0/6	0	None	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., risk-based concentrations for soil and maximum contaminant levels for water).

Figure 3-8. Chlorine-36 detections in the Subsurface Disposal Area in Fiscal Year 2005.

Table 3-27. Concentration ranges, detection rates, and maximum contaminant level exceedances of chlorine-36 in sampled media since monitoring began.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	6.9	5/72	0	None	3.5 ± 0.9	17 ± 3	32.3 ± 1.6 _J ^c
Vadose zone (35 to 140 ft)							
Soil moisture	4.1	4/98	0	None	5.6 ± 0.9	22 ± 4	31.6 ± 0.9
Vadose zone (140 to 250 ft)							
Soil moisture	1.4	1/72	0	None	NA	NA	8.7 ± 1.0
Vadose zone (>250 ft)							
Soil moisture	0.0	0/35	0	None	NA	NA	NA
Aquifer	0.0	0/78	0	None	NA	NA	NA
Aquifer field blanks	0.0	0/15	0	None	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

c. Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the Cl-36 result because of analytical quality control anomalies. The result is questionable and should be used only as an estimated quantity.

3.5 Tritium

Tritium is produced naturally by interactions of cosmic rays and atmospheric gases and artificially by nuclear reactor operations. Though not a contaminant of potential concern, tritium is monitored for the following reasons:

- Tritium is a mobile constituent collocated with C-14. Both C-14 and tritium are dual-phase constituents that partition into vapor-phase and dissolved-phase components. Thus, tritium monitoring provides trend detection and early indication of possible C-14 migration.
- A substantial fraction of the small amount of tritium (and C-14) released from waste each year migrates to the atmosphere. Distribution and migration are important to the overall understanding of design requirements for a surface barrier, which is an assumed component of future remedial action at the SDA (Holdren and Broomfield 2004).
- Tritium is a contaminant of interest for the ongoing LLW disposal operation (Parsons, Seitz, and Keck 2005).

Approximately $2.67\text{E}+06$ Ci of tritium was buried in the SDA, according to inventory estimates through 1999, and an additional $1.12\text{E}+04$ Ci is projected to be added by 2009, for a total of $2.68\text{E}+06$ Ci (Holdren et al. 2006).

3.5.1 Vadose Zone and Aquifer

In FY 2005, many samples collected from lysimeters in the vadose zone and from the aquifer near RWMC show tritium to be present at low concentrations. In FY 2005, 127 tritium analyses were performed on soil-moisture and perched water samples, and 34 analyses were performed on aquifer samples taken near RWMC. Low concentrations (i.e., around 500 pCi/L) were detected at various locations inside and outside the SDA, except at location R2006. Lysimeter R2006:DL46 is located at the east end of the SDA, and the concentration measured in August 2005 was 16,700 pCi/L, which was about a 50% increase from the previous sampling event in May 2005 (i.e., 11,000 pCi/L). Positive detections of tritium in RWMC aquifer monitoring wells varied from about 200 to 1,400 pCi/L. Recent findings of a 2-year study conducted by WAG 10 (DOE-ID 2006) indicate tritium found in RWMC wells north-northeast of RWMC is likely from the Idaho Nuclear Technology Engineering Center (INTEC) and possibly the Reactor Technology Complex (RTC) (see additional discussion in Section 3.13.2.2 and 3.13.2.3). A table listing concentrations was not generated because tritium is not a contaminant of concern, and measured concentrations, trends, and locations where tritium was detected in soil-moisture and aquifer samples in FY 2005 are typical of historical and previously reported data.

3.5.2 Soil-Gas Monitoring near SVR 20

The original GSP-1 and Type B vapor sampling ports at SVR 20 were removed in summer 2004 to facilitate grouting operations and were replaced with ports placed in two new monitoring wells in August and November 2004. The new sampling locations, (i.e., RWMC-2022 and RWMC-2023) each contain four vapor ports at depths ranging from 1.2 to 5.9 m (3.9 to 19.4 ft). In FY 2005, after grouting operations in summer 2004, soil-gas samples were collected from newly installed ports. Table 3-28 summarizes soil-gas data for the first year of sampling. Maximum soil concentrations measured with these ports were approximately three orders of magnitude less than those previously recorded at location GSP-1. Unfortunately, measurements with the new ports are not directly comparable to previous sampling results because the new sampling ports are located much farther from the beryllium blocks.

Table 3-28. Summary of tritiated water activity (pCi of tritium per mL water) in soil-gas samples collected from ports in wells RWMC-2022 and RWMC-2023 at SVR 20 in Fiscal Year 2005.

Date	RWMC-2022				RWMC-2023			
	Depth (m)				Depth (m)			
	1.2	2.7	4.6	5.9	1.2	2.7	4.6	5.6
09/29/2004	7,553	106	146	242	—	—	—	—
12/07/2004	8,342	91	155	159	—	—	—	—
12/14/2004	—	—	—	—	1,459	123	98	4
02/21/2005	8,103	94		122	—	—	—	—
02/24/2005	—	—	—	—	1,612	112	53	3
05/12/2005	6,323	90	99	104	1,797	46	14	2
06/09/2005	6,355	95	95	103	1,231	46	13	3
07/11/2005	6,992	105	107	105	506	75	17	3
08/11/2005	7,183	97	98	107	408	76	22	—
09/20/2005	6,684	101	97	107	424	90	18	4

— = indicates no sample collected

3.5.2.1 Disposals and Historical Monitoring of Tritium in Soil Gas at SVR 20. SVR 20 contains large amounts of tritium from the disposal of activated beryllium. In 1993, six beryllium reflector blocks from Core 3 of the Advanced Test Reactor were buried in SVR 20. The blocks contained an estimated total of $1.8\text{E}+05$ Ci tritium at time of disposal (Sebo et al. 2005). In 1994, instrumentation was installed at the SVR 20 disposal site. Suction lysimeters, thermistors, vapor ports, and neutron moisture probe access tubes were placed adjacent to the auger hole between 2.7 and 6.2 m (8.9 and 20.3 ft) below grade (Ritter and McElroy 1999). The GSP-1 ports may have been installed in the disturbed soil that fills the auger hole, and large concentration gradients are expected in the vicinity of the beryllium. Occasional measurements of tritium in soil gas were made in 1995 and 1996, and routine sampling began in January 1997. Soil-gas sampling for tritium was temporarily discontinued at SVR 20 after March 2004 because grouting operations required removal of existing instrumentation in early summer 2004. Data leading up to the port removals showed a long-term, accelerating trend toward increased tritium concentration through the active monitoring period. The tritium concentration in soil 2.7 m (8.9 ft) deep was consistently greater than the activities measured at 4.5 and 6.3-m (15 and 21-ft) depth, but the concentrations at all depths fluctuated similarly and had the same general long-term trend. Generally, the maximum values were reached in the late summer or fall, and those maxima increased by approximately an order of magnitude over 4 years (Koeppen et al. 2005).

3.5.2.2 Post-Grout Monitoring of Tritium in Soil Gas at SVR 20. Sets of four soil vapor ports were installed in each of two new wells (i.e., RWMC-2022 and RWMC-2023) to monitor C-14 and tritium in SVR 20 after grout injection. Wells RWMC-2022 and RWMC-2023 are located 5.8 and 8.8 m (19 and 29 ft), respectively, from the activated beryllium disposals in SVR 20. Both wells have ports open at depths of 1.2, 2.7, and 4 m (4, 9, and 13 ft). Because of differences in depth to the basalt layer, the bottom port in RWMC 2022 is located 5.9 m (19.5 ft) deep, and the bottom port in RWMC-2023 is located 5.6 m (18.5 ft) deep. Sampling began in September and December 2004 on RWMC-2022 and RWMC-2023, respectively. Table 3-28 summarizes soil-gas data for the first year of sampling. Maximum concentrations measured at these ports were approximately three orders of magnitude less than concentrations previously measured closer to the beryllium, using GSP-1. The difference is likely due to increased dispersion in the subsurface and loss of tritium to the atmosphere. There is a four-fold difference between the maximum concentrations recorded 1.2 m (4 ft) deep in RWMC-2022 and at the same depth in RWMC-2023, 3 m (9.8 ft) farther from the buried beryllium. Concentrations measured at each port generally decreased with increasing depth, in contrast with observations at GSP-1, where concentrations at the 4.5-m (14.8-ft) depth were consistently less than those at 2.7 and 6.2 m (8.9 and 20.3 ft). After May 2005, no differences were measured between tritium concentrations at 2.7, 4.6, and 5.9 m (9, 13, and 19.5 ft) depths in RWMC-2022. A 2.4-fold decrease was observed in tritium activity in RWMC-2023 at the 1.2-m (4-ft) port between June and July 2005. Concentrations measured in samples from ports below 1.2 m (4 ft) decreased to a lesser degree after the initial sampling in September and December 2004 in RWMC-2022 and RWMC-2023, respectively.

3.5.2.3 Ambient Air Sampling for Tritium at SVR 20. In 2005, after installation of the new monitoring ports, passive air sampling for tritium was conducted near Well RWMC-2022, approximately 5 m (16.4 ft) cross-wind from the original sampling location. Results from the pre- and post-grouting samples are not comparable, and suitability of the new location will be reviewed after additional data have been collected. Figure 3-9 presents results for all airborne tritium measurements since 1995. These include measurements made by the INL Sitewide Monitoring Program (formerly the Idaho National Engineering and Environmental Laboratory Environmental Monitoring Program) and Idaho State University staff supporting the INL Oversight Program. The INL Sitewide Monitoring Program conducted continuous sampling for airborne tritium at SVR 20 from 1995 to 2002, downwind of the area source with respect to the nighttime primary wind direction. Emissions during 2005 were estimated, assuming the pre- and post-grouting source characteristics are the same; however, differences between pre- and post-grouting emission sources have not been determined. Table 3-29 lists estimated annual emissions of tritium from buried activated beryllium at SVR 20 from calendar years 1995 through 2005.

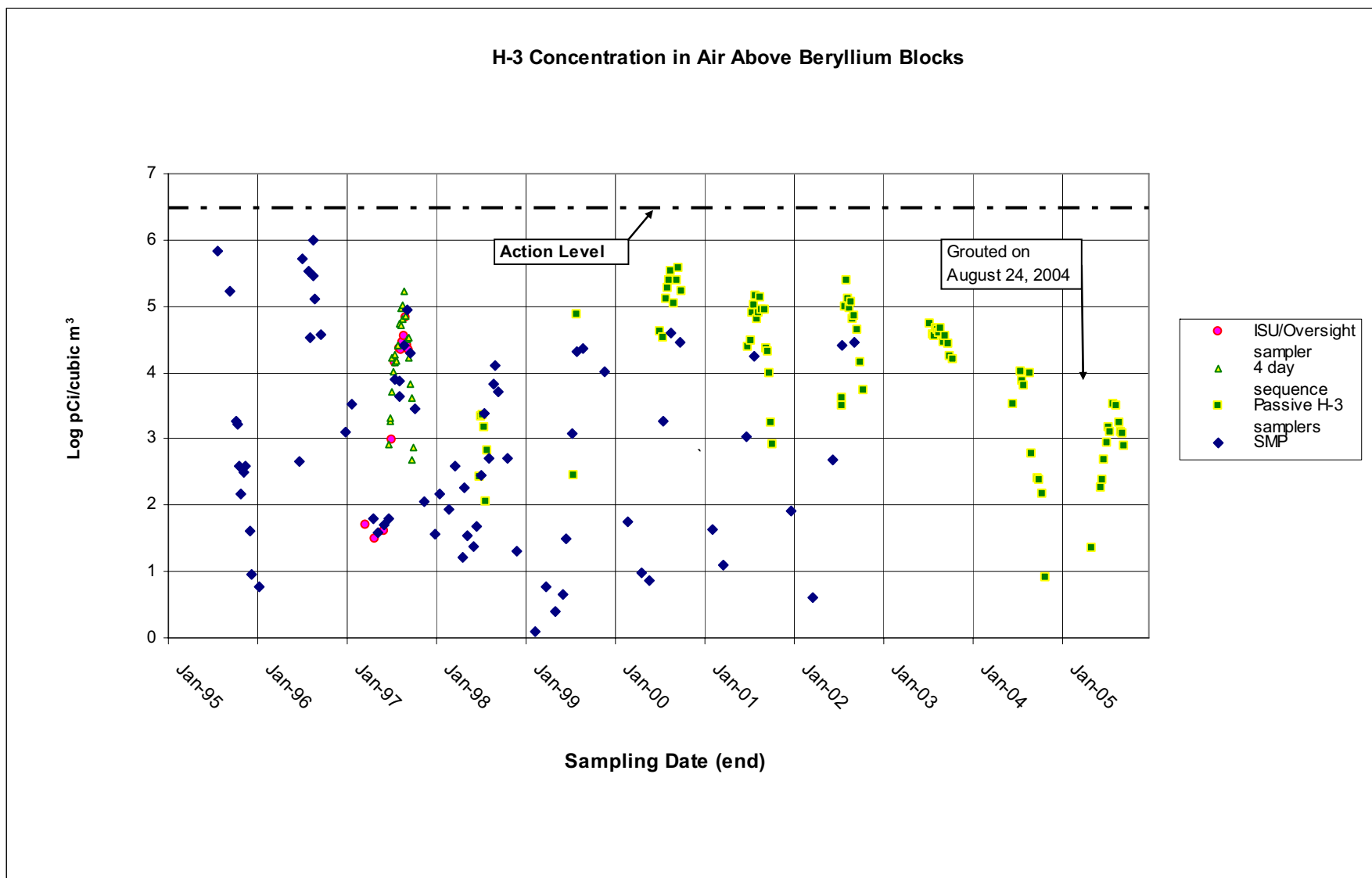


Figure 3-9. Results of airborne tritium sampling at SVR 20.

Table 3-29. Estimated annual emission of tritium to air from buried activated beryllium at SVR 20.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Emission (Ci) ^a	30	30	3	0.5	3	20	10	10	5	2	1

a. Emissions for Calendar Years 1995 to 1999 are based on Site-wide environmental monitoring sampling, and emissions for Calendar Years 2000 through 2005 are based on passive sampling results.

3.5.2.4 Historical Monitoring of Ambient Air at SVR 20. A substantial fraction of tritium released from buried waste migrates to the atmosphere. Ambient air sampling has been conducted as part of the characterization of the source environment.

During initial years of the monitoring program at SVR 20, actively pumped tritium samplers were used by the INL Sitewide Monitoring Program and the Idaho State University Program. Routine passive airborne tritium sampling (Wood and Workman 1992; Wood 1996) began in 2000 as a relatively inexpensive means to sample over 1-week periods between June through October each year, when the peak emissions occur. Until mid-summer 2004, passive samples were collected at 1 m (3.2 ft) elevation above the edge of the backfilled auger hole, downwind with respect to the primary daytime primary wind direction. Results from INL Sitewide Monitoring Program samplers and the 2000 to 2002 passive samplers show similar temporal fluctuations, but are not comparable because sampler inlets were positioned on opposite sides of the emission source. This likely resulted in consistent long-term differences in dispersion. Based on results for FY 2000 through 2002, the passive samplers were exposed to air concentrations that are typically an order of magnitude greater than INL Sitewide Monitoring Program samplers. After mid-summer 2004, passive sampling was conducted near RWMC-2022, approximately 5 m (16.4 ft) cross-wind from the original sampling location. Results from pre- and post-grouting samples are not comparable, and suitability of the new location will be reviewed after additional data have been collected. Results are presented in Figure 3-9.

The data from ambient air sampling are used to develop emission estimates by calendar year for all buried beryllium as required by the National Emission Standards for Emissions of Radionuclides (40 CFR 61, Subpart H).

3.5.2.5 Summary of Tritium in Soil Gas. This subsection provides a summary of tritium activity in soil gas at SVR 20.

- One year after grouting, tritium activity in soil gas in the shallow subsurface at SVR 20 remains above background levels.
- Soil concentrations at SVR 20 decrease with distance from the grouted activated beryllium disposal and are greatest nearest the soil surface. The relatively high tritium concentrations measured 1.2 m (3.9 ft) below grade in RWMC-2022 and RWMC-2023 could be caused by conditions at the source.
- While the tritium concentration has decreased 8.8 m (28.9 ft) laterally from the disposal, that decrease is not matched proportionally 5.8 m (19 ft) from the disposal. Greater fluctuations in concentration have been observed in the GSP-1 ports.
- Tritium concentrations in air over SVR 20 remain elevated.

3.5.3 Summary of Tritium

Tritium has been detected at low concentrations in numerous vadose zone soil-moisture samples and at high concentrations in vapor and soil-gas samples near buried beryllium. One year after grouting, tritium activity in soil gas in the shallow subsurface at SVR 20 remains greater than background levels. However, activity measurements pre- and post-grouting are not directly comparable because of differences in monitoring locations and the immediate source environment.

Tritium is regularly detected in six aquifer monitoring wells located in the northeastern corner of RWMC. Historical data and data collected for the recent WAG 10 geochemical study (DOE-ID 2006) support the premise that tritium on the northern side of RWMC is attributable to INTEC.

3.6 Iodine-129

Iodine-129 is produced from nuclear reactor operations and weapons testing, and it occurs naturally in the environment through interactions of cosmic rays with atmospheric gases and from the spontaneous fission of U-238. It decays by the emission of beta particles and has a half-life of 1.57E+07 years.

This section summarizes I-129 monitoring data for all sample media; data for the vadose zone and aquifer also are evaluated against comparison concentrations shown in Table 2-2.

CAVEAT: *Concentrations of I-129 measured in soil-moisture samples may not be representative of actual concentrations in the vadose zone because the process of sampling soil moisture (i.e., vacuum) may cause a portion of I-129, depending on oxidation conditions, to volatilize from the water sample. While volatilization is thermodynamically favored, it is probably kinetically inhibited. If volatilization is occurring, then measured concentrations may be somewhat lower than actual concentrations in the vadose zone. Detecting I-129 in soil-moisture samples also is complicated by high detection limits (e.g., 40 pCi/L for 50-mL samples).*

3.6.1 Buried Waste Inventory

Approximately 0.138 Ci of I-129 was buried in the SDA through 1999, and an additional 0.0492 Ci is projected to be added by 2009, for a total of 0.188 Ci (Holdren et al. 2006).

3.6.2 Vadose Zone

This section discusses distributions of I-129 in vadose zone soil moisture and perched water in shallow-, intermediate-, and deep-depth intervals.

3.6.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 33 analyses for I-129 were performed on soil-moisture samples collected from 17 shallow-depth lysimeters near RWMC, with no positive detections.

Since 1997, 110 analyses for I-129 were performed on shallow-depth lysimeter samples, with three positive detections ranging in concentration from 22 to 53 pCi/L. Table 3-30 summarizes historical data and occurrences of I-129 detections in the shallow vadose zone samples since routine monitoring began in 1997. As can be seen in Table 3-30, detections are very rare, and this may be because I-129 is not widespread throughout the vadose zone at detectable concentrations. A sample was collected from Lysimeter 98-3:L37, which is the first time in 2 years that any pore water has been obtained from this location. Since installation in 1998, this lysimeter has yielded water only one other time (i.e., July 2003);

disappointingly, the sample volume was insufficient to perform sample analysis. The sample volume collected in August 2005 was also small, but sufficient to perform I-129 analysis. Section 3.5.4 summarizes concentration ranges, detection rates, and MCL exceedances since 1997.

3.6.2.2 *Lysimeter Samples at Depths from 35 to 140 ft.* In FY 2005, 34 analyses for I-129 performed on soil-moisture samples were collected from 15 intermediate-depth lysimeters near RWMC, with no positive detections.

Since routine monitoring began in 1997, 57 analyses for I-129 were performed on intermediate-depth vadose zone samples, with no positive detections; therefore, a table of occurrences is not presented. Section 3.5.4 summarizes concentration ranges, detection rates, and MCL exceedances since 1997.

3.6.2.3 *Lysimeter and Perched Water Samples at Depths Greater Than 140 ft.* In FY 2005, 47 analyses for I-129 were performed on soil-moisture samples collected from 21 lysimeters and one perched water well; no positive detections resulted.

Since routine monitoring began in 1997, 83 analyses for I-129 were performed in the deep vadose zone, with no positive detections; therefore, a table of occurrences is not presented. Section 3.5.4 summarizes concentration ranges, detection rates, and MCL exceedances since 1997.

Table 3-30. Iodine-129 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Iodine-129 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-3: L37	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																				
	2																				
	3																				
	4																				
1998	1																				
	2																				
	3																				
	4																				
1999	1																				
	2																				
	3																				
	4																				
2000	1																				
	2																				
	3																				
	4																				
2001	1																				
	2																				
	3																				
	4																				

Table 3-30. (continued).

Iodine-129 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-3: L37	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2002	1																				
	2																				
	3																				
	4																				
2003	1																				
	2																				
	3																				
	4																				
2004	1																				
	2																				
	3																				
	4																				
2005	1																				
	2																				
	3																				
	4																				
		Analysis was performed, but I-129 was not detected.																			
		I-129 was detected (pCi/L). Reported concentrations could be biased low (see caveat in Section 3.5).																			

3.6.3 Aquifer

In FY 2005, 34 analyses for I-129 were performed on aquifer samples collected from 15 monitoring wells near RWMC, and no positive detections resulted.

Table 3-31 shows detection occurrences in aquifer samples since 1997. Since 1997, 429 analyses were performed; four positive detections were found, two of which exceeded the drinking water MCL of 1 pCi/L. The four detections occurred between 1997 and October 1998, and no I-129 detections have occurred since that time. Section 3.5.4 summarizes concentration ranges, detection rates, and MCL exceedances since 1997.

Table 3-31. Iodine-129 detections in aquifer monitoring wells since 1997.

Iodine-129 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11-A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW2	USGS -127
1997	1																
	2																
	3		1.7														
	4																
1998	1													0.59			
	2																
	3																
	4										0.98						
1999	1														1.5		
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																

Table 3-31. (continued).

Table 5-51 (continued).

Iodine-129																	
Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11-A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW2	USGS -127
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis.																	
For comparison, maximum contaminant level = 1 pCi/L.																	
	Analysis performed, but I-129 was not detected.																
	I-129 was detected (pCi/L).																
	Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.																

3.6.4 Summary of Iodine-129

In FY 2005, I-129 was not detected above method detection limits in any soil-moisture, perched water, or aquifer samples collected near RWMC. Table 3-32 shows concentration ranges and detection frequencies in FY 2005, and Table 3-33 shows concentration ranges, detection frequencies, and exceedances since 1997; note that I-129 detections are rare.

Table 3-32. Concentration ranges, detection frequencies, and maximum contaminant level exceedances of iodine-129 in Fiscal Year 2005.

Table 2-2. Concentration ranges, detection frequencies, and maximum contaminant level exceedances of radon-222 in Fiscal Year 2003.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	0.0	0/33	0	None	NA	NA	NA
Vadose zone (35 to 140 ft)							
Soil moisture	0.0	0/34	0	None	NA	NA	NA
Vadose zone (140 to 250 ft)							
Soil moisture	0.0	0/27	0	None	NA	NA	NA
Vadose zone (>250 ft)							
Soil moisture	0.0	0/20	0	None	NA	NA	NA
Aquifer	0.0	0/34	0	None	NA	NA	NA
Aquifer field blanks	0.0	0/6	0	None	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

Table 3-33. Concentration ranges, detection rates, and maximum contaminant level exceedances of iodine-129 in sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone 0 to 35 ft)							
Soil moisture	2.7	3/110	3	98-1, 98-5, W25	22 ± 7	35 ± 10	53 ± 17
Vadose zone (35 to 140 ft)							
Soil moisture	0.0	0/57	0	None	NA	NA	NA
Vadose zone (140 to 250 ft)							
Soil moisture	0.0	0/54	0	None	NA	NA	NA
Vadose zone (>250 ft)							
Soil moisture	0.0	0/29	0	None	NA	NA	NA
Aquifer	0.9	4/429	2	M7S and M10S	0.59 ± 0.17	1.2 ± 0.3	1.7 ± 0.4
Aquifer field blanks	0.0	0/35	0	None	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

3.7 Neptunium-237

Neptunium-237 is an anthropogenic TRU radionuclide that is a product of nuclear reactor operations and a decay product of Am-241. It decays by the emission of alpha particles and has a half-life of 2.14E+06 years.

Neptunium-237 monitoring data for all sample media are summarized below. Sampling data in this section are evaluated against the comparison concentrations shown in Table 2-2. No surface soil data are available because Np-237 is not a target analyte for surface sampling and analysis.

3.7.1 Buried Waste Inventory

Approximately 0.118 Ci of Np-237 was buried in the SDA through 1999, and an additional 0.0228 Ci is projected to be added by 2009, for a total of 0.141 Ci (Holdren et al. 2006).

3.7.2 Vadose Zone

Though it can be mobile, Np-237 has never been detected in vadose zone soil-moisture and perched water samples near RWMC since it became a vadose zone analyte in 2000. Results for Np-237 are presented in the following sections for soil and soil-moisture samples.

3.7.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 26 Np-237 analyses were performed on soil-moisture samples collected from 13 shallow-depth lysimeters near RWMC, with no positive detections.

Historically, 87 analyses have been performed in the shallow vadose zone, and Np-237 has never been detected since monitoring for Np-237 began in 2000.

3.7.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 28 Np-237 analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters near RWMC, with no positive detections.

Historically, 87 analyses have been performed in the intermediate vadose zone, and Np-237 has never been detected since monitoring for Np-237 began in 2000.

3.7.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 34 Np-237 analyses were performed on samples collected from 16 lysimeters and one perched water well near RWMC, with no positive detections.

Historically, 76 analyses have been performed in the deep vadose zone, and Np-237 has never been detected since monitoring for Np-237 began in 2000.

3.7.3 Aquifer

In FY 2005, 35 Np-237 analyses were performed on aquifer samples collected from 15 monitoring wells near RWMC, with no positive detections.

Historically, 378 analyses were performed, and four positive detections have occurred near RWMC since Np-237 monitoring began in 1998. Concentrations ranged from 0.07 to 0.38 pCi/L, and each detection was in a different monitoring well. None of the concentrations exceeded the MCL of 15 pCi/L (total alpha). Though replicate analysis was performed, no detections were confirmed, and subsequent

sampling events have not yielded detections. Therefore, a table showing occurrences is not presented. Section 3.7.4 presents historical concentration ranges, detection frequencies, and MCL exceedances.

3.7.4 Summary of Neptunium-237

In FY 2005, Np-237 was not detected in the vadose zone, perched water, or aquifer. Table 3-34 presents concentration ranges, detection frequencies, and MCL exceedances in FY 2005, and Table 3-35 presents detection frequencies and concentration ranges since monitoring for Np-237 began in the aquifer in 1998 and in the vadose zone in 2000.

Table 3-34. Concentration ranges, detection frequencies, and maximum contaminant level exceedances of neptunium-237 in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Range of Detected Concentrations (pCi/L)		
				Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)						
Soil moisture	0.0	0/26	0	NA	NA	NA
Vadose zone (35 to 140 ft)						
Soil moisture	0.0	0/28	0	NA	NA	NA
Vadose zone (140 to 250 ft)						
Soil moisture	0.0	0/16	0	NA	NA	NA
Vadose zone (>250 ft)						
Soil moisture	0.0	0/18	0	NA	NA	NA
Aquifer	0.0	0/35	0	NA	NA	NA
Aquifer field blanks	0.0	0/0	0	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

Table 3-35. Concentration ranges, detection rates, and maximum contaminant level exceedances of neptunium-237 in sampled media since monitoring began.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Range of Detected Concentrations (pCi/L)		
				Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)						
Soil moisture	0.0	0/87	0	NA	NA	NA
Vadose zone (35 to 140 ft)						
Soil moisture	0.0	0/87	0	NA	NA	NA
Vadose zone (140 to 250 ft)						
Soil moisture	0.0	0/52	0	NA	NA	NA
Vadose zone (>250 ft)						
Soil moisture	0.0	0/24	0	NA	NA	NA
Aquifer	1.1	4/378	0	0.07 ± 0.02	0.20 ± 0.03	0.38 ± 0.04
Aquifer field blanks	0.0	0/33	0	NA	NA	NA

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

3.8 Plutonium-238, Plutonium-239, and Plutonium-240

All plutonium isotopes are anthropogenic and TRU products of nuclear reactor operations or nuclear weapons production, deployment, and testing. Plutonium-238, -239, and -240 decay by emission of alpha particles and have half-lives of $8.77\text{E}+01$, $2.41\text{E}+04$, and $6.56\text{E}+03$ years, respectively.

CAVEAT: *Some low-level detections of Pu-238 could be false positives. A study conducted at the Savannah River Site shows the occurrence of false positive results for Am-241 can be fairly common at commercial laboratories (Kubilius et al. 2004). False positives for Pu-238 determined by alpha spectroscopy are attributed to incomplete separation from natural Th-228 (Kubilius et al. 2004). At very low concentrations, determining whether a reported, stand-alone Pu-238 detection is false positive is nearly impossible. Therefore, the data evaluator or user can only speculate on its validity based on analytical experience and knowledge, together with an understanding of the waste type(s) near the sample location.*

Plutonium monitoring data for all media are summarized in the following subsections. Sampling data in this section are evaluated against the comparison concentrations in Table 2-2.

3.8.1 Buried Waste Inventory

Approximately $2.08\text{E}+03$ Ci of Pu-238, $6.41\text{E}+04$ Ci of Pu-239, and $1.46\text{E}+04$ Ci of Pu-240 primarily from the Rocky Flats Plant was buried in the SDA through 1999. An additional amount of alpha-contaminated LLW (i.e., waste with TRU concentrations less than 10 nCi/g), including $4.91\text{E}-01$ Ci of Pu-238, $5.07\text{E}-01$ Ci of Pu-239, and $1.83\text{E}-01$ Ci of Pu-240, is projected to be added by 2009, which will have a negligible effect on totals. Most plutonium came from weapons manufacturing waste, but INL reactor operations also contributed a portion (Holdren et al. 2006).

3.8.2 Vadose Zone

This section discusses distribution of plutonium in vadose zone soil moisture and perched water at monitored depth intervals.

3.8.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 33 analyses for Pu-238 and Pu-239/240 were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, with no positive detections.

Since 1997, 185 Pu-238 and 186 Pu-239/240 analyses were performed on shallow-depth lysimeter samples, with seven Pu-238 detections and one Pu-239/240 detection. Plutonium-238 concentrations ranged from 0.9 to 24 pCi/L, and the Pu-239/240 concentration was 0.7 pCi/L. Tables 3-36 and 3-37 depict historical occurrences of Pu-238 and Pu-239/240, respectively, in the shallow vadose zone since routine monitoring began in 1997. Section 3.8.4 presents concentration ranges, detection rates, and MCL exceedances since 1997.

It should be noted that seven Pu-238 detections and one Pu-239/240 detection have occurred in this depth interval since 1997. The higher number of Pu-238 detections than Pu-239/240 is unusual because weapons manufacturing waste buried in the SDA contains mostly Pu-239/240. Approximately 50 times more Pu-239/240 is present than Pu-238 in weapons production waste, so not detecting Pu-239/240 raises many suspicions and questions as to the validity and actual presence of plutonium in many of these historical samples (see caveat in Section 3.8).

Table 3-36. Plutonium-238 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																			
	2																			
	3																			
	4							24												
1998	1																			
	2							2.2												
	3			5.6		8.5														
	4																			
1999	1																			
	2																			
	3																			
	4																			
2000	1																			
	2																			
	3																			
	4		0.88			2.3														
2001	1						3.7													
	2																			
	3																			
	4																			
2002	1																			
	2																			
	3																			
	4																			

Table 3-36. (continued).

Plutonium-238																				
Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2003	1																			
	2																			
	3																			
	4																			
2004	1																			
	2																			
	3																			
	4																			
2005	1																			
	2																			
	3																			
	4																			
Note: The highest result is reported for duplicate samples or reanalysis.																				
For comparison, maximum contaminant level = 15 pCi/L (total alpha).																				
	Analysis was performed, but Pu-238 was not detected.																			
	Pu-238 was detected (pCi/L). Some reported results could be false positives (see caveat in Section 3.8).																			

Table 3-37. Plutonium-239/240 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

		Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																		
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																			
	2																			
	3																			
	4																			
1998	1																			
	2																			
	3																			
	4																			
1999	1																			
	2																			
	3																			
	4																			
2000	1																			
	2																			
	3																			
	4																			
2001	1																			
	2																			
	3																			
	4																			
2002	1																			
	2																			
	3																			
	4																			

Table 3-37. (continued).

Table 3-37 (continued).

		Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																		
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2003	1																			
	2																			
	3																			
	4																			
2004	1																			
	2																			
	3																			
	4																			
2005	1																			
	2																			
	3																			
	4																			
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, maximum contaminant limit = 15 pCi/L (total alpha).																				
	Analysis was performed, but Pu-239/240 was not detected.																			
	Pu-239/240 was detected (pCi/L).																			

Alternatively, detecting Pu-238 without Pu-239/240 could be indicative of reactor operations waste, where Pu-238 activity levels are generally higher than Pu-239/240. However, without the presence of Pu-239/240, activity ratios cannot be calculated to conclusively establish the source of Pu-238.

3.8.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 39 Pu-238 and Pu-239/240 analyses were performed on soil-moisture samples collected from 15 intermediate-depth lysimeters near RWMC, with no positive detections.

Since 1997, 155 Pu-238 and 155 Pu-239/240 analyses were performed on intermediate-depth lysimeter samples, with three Pu-238 detections and three Pu-239/240 detections. Plutonium-238 concentrations ranged from 3.1 to 11.6 pCi/L, and Pu-239/240 ranged from 0.34 to 3.3 pCi/L. Historical results of Pu-238 and Pu-239/240 in the intermediate-depth vadose zone since routine monitoring began in 1997 are depicted in Tables 3-38 and 3-39, respectively. Section 3.8.4 presents historical concentration ranges, detection rates, and MCL exceedances.

Three Pu-238 and three Pu-239/240 detections have occurred in the intermediate-depth interval since 1997, though none are associated with the same lysimeter sample or sampling date, except for Lysimeter D15:DL06. Both Pu-238 and Pu-239/240 were detected in Lysimeter D15:DL06; however, Pu-238 was detected at a higher concentration than Pu-239/240. Detecting Pu-238 and not Pu-239/240, or detecting Pu-238 at higher concentrations than Pu-239/240, is unusual because most of the waste buried in the SDA is weapons manufacturing waste, which comprises mostly Pu-239/240. Plutonium-239/240 accounts for approximately 50 times more activity in weapons manufacturing waste than Pu-238, so concentrations of Pu-239/240 in these historical samples should have been much higher than Pu-238. These data anomalies create questions about the validity and actual presence of plutonium in some historical samples, making it likely that some Pu-238 results are false positive (see caveat in Section 3.8).

Alternatively, Pu-238 detections without Pu-239/240 or Pu-238 concentrations higher than Pu-239/240 also could be indicative of reactor operations waste, where Pu-238 activity levels generally are higher than Pu-239/240. Other than location D15:DL06, no monitoring locations exhibited detections of both Pu-238 and Pu-239/240; therefore, activity ratios cannot be calculated, and the source of plutonium is indeterminable. At location D15:DL06, Pu-238 and Pu-239/240 were detected only once. Though the activity ratio is suggestive of reactor operations waste, insufficient data are available to conclusively establish the source of plutonium.

Table 3-38. Plutonium-238 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Plutonium-238 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																		
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																	
	2																	
	3																	
	4	11.6	3.3	3.1														
1998	1																	
	2																	
	3																	
	4																	
1999	1																	
	2																	
	3																	
	4																	
2000	1																	
	2																	
	3																	
	4																	
2001	1																	
	2																	
	3																	
	4																	
2002	1																	
	2																	
	3																	
	4																	

Table 3-38. (continued).

Table 3-30 (continued).

Plutonium-238 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																		
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
2003	1																	
	2																	
	3																	
	4																	
2004	1																	
	2																	
	3																	
	4																	
2005	1																	
	2																	
	3																	
	4																	
Note: The highest result is reported for duplicate samples or reanalysis.																		
For comparison, maximum contaminant level = 15 pCi/L (total alpha).																		
	Analysis was performed, but Pu-238 was not detected.																	
	Pu-238 was detected (pCi/L). Some reported results could be false positives (see caveat in Section 3.8).																	

Table 3-39. Plutonium-239/240 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

		Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																	
	2																	
	3																	
	4			1.1														
1998	1																	
	2																	
	3																	
	4																	
1999	1																	
	2																	
	3																	
	4																	
2000	1																	
	2																	
	3																	
	4																	
2001	1																	
	2																	
	3																	
	4																	
2002	1																	
	2																	
	3																	
	4																	

Table 3-39. (continued).

		Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	R2004: DL50	R2006: DL46	TW1: DL04
2003	1																	
	2																	
	3																	
	4																	
2004	1																	
	2																	
	3																	
	4																	
2005	1																	
	2																	
	3																	
	4																	
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, maximum contaminant level = 15 pCi/L (total alpha).																		
	Analysis was performed, but Pu-239/240 was not detected.																	
	Pu-239/240 was detected (pCi/L).																	

3.8.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 60 analyses for Pu-238 and Pu-239/240 were performed on soil-moisture and perched water samples collected from 25 monitoring wells near RWMC, with no positive detections.

Since 1997, 173 Pu-238 and 170 Pu-239/240 analyses were performed on deep lysimeter samples, with one Pu-238 and one Pu-239/240 detection. The detected concentration for Pu-238 was 4.8 pCi/L, and 2.7 pCi/L for Pu-239/240. Tables 3-40 and 3-41 summarize historical data and occurrences for Pu-238 and Pu-239/240 in deep vadose zone samples since routine monitoring began in 1997. Historically, as shown in Tables 3-40 and 3-41, detections are sporadic with no apparent trends or spatial patterns. Two detections each for Pu-238 and Pu-239/240 were made in the intermediate-depth interval since 1997; each occurred on different sampling dates. Detections of Pu-239/240 at monitoring location O6:DL26 and Well USGS-92 were one-time occurrences because Pu-239/240 has not been detected at these locations since that time. Plutonium-238 was detected twice in perched water Well USGS-92; however, detecting Pu-238 without Pu-239/240 is unusual because most waste buried in the SDA is weapons manufacturing waste, which comprises mostly Pu-239/240. This data anomaly creates questions about the validity and actual presence of plutonium at this monitoring location (see caveat in Section 3.8). Alternatively, Pu-238 detections without Pu-239/240 could be indicative of reactor operations waste, where Pu-238 activity levels are generally higher than Pu-239/240. However, without the presence of Pu-239/240, activity ratios cannot be calculated to conclusively establish the source of Pu-238. Section 3.8.4 summarizes concentration ranges, detection frequencies, and exceedances since 1997.

Table 3-40. Plutonium-238 detections in deep (greater than 140 ft) lysimeters and perched water wells since 1997.

Plutonium-238																																			
Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																																			
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL61	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	R2006: DL43	S1898: DL40	USGS-092	
1997	1																																		
	2																																		
	3																																	1.4*	
	4																																		
1998	1																																		
	2																																		
	3																																		
	4																																		
1999	1																																		
	2																																		
	3																																		
	4																																		
2000	1																																		
	2																																		
	3																																		
	4																																		
2001	1																																		4.8
	2																																		
	3																																		
	4																																		
2002	1																																		
	2																																		
	3																																		
	4																																		
2003	1																																		
	2																																		
	3																																		
	4																																		
2004	1																																		
	2																																		
	3																																		
	4																																		
2005	1																																		
	2																																		
	3																																		
	4																																		
Note: The highest result is reported for duplicate samples or reanalysis.																																			
* = result is for filtered sediment, not filtrate.																																			
For comparison, maximum contaminant level = 15 pCi/L total alpha.																																			
	Analysis was performed for Pu-238, but none was detected.																																		
	Pu-238 was detected (pCi/L), but some reported results could be false positives (see caveat in Section 3.8).																																		

3.8.3 Aquifer

In FY 2005, 35 analyses for Pu-238 and Pu-239/240 were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, with no positive detections.

Since 1997, 567 Pu-238 and 564 Pu-239/240 sample analyses have been performed, with 13 Pu-238 and two Pu-239/240 detections. Concentrations for Pu-238 ranged from 0.018 to 0.37 pCi/L, and Pu-239/240 ranged from 0.034 to 0.09 pCi/L. Historical data show sporadic detections of Pu-238 and Pu-239/24, but no evident trends or spatial patterns. Distribution of Pu-238 and Pu-239/240 detections in aquifer samples since 1997 are shown in Tables 3-42 and 3-43, respectively. Section 3.8.4 presents concentration ranges, detection frequencies, and MCL exceedances since 1997.

Since 1997, 13 positive Pu-238 detections and two Pu-239/240 detections have occurred. None of the historical detections were confirmed by reanalysis, except for two Pu-238 samples in October 2000 (i.e., Wells M7S and M11S). The high number of Pu-238 detections versus Pu-239/240 detections is highly unusual and not characteristic of plutonium buried in the SDA. Weapons manufacturing waste contains about 50 times more Pu-239/240 than Pu-238 activity; therefore, the preponderance of Pu-238 detections in the aquifer around RWMC are anomalous and raise questions about the validity and actual presence of plutonium in these historical samples (see caveat in Section 3.8). Alternatively, Pu-238 detections without Pu-239/240, or Pu-238 concentrations higher than Pu-239/240, also could be indicative of reactor operations waste, where Pu-238 activity levels are generally higher than Pu-239/240. However, without the presence of Pu-239/240, activity ratios cannot be calculated to conclusively establish the source of Pu-238 in aquifer samples. Plutonium-238 and Pu-239/240 were both detected once, at locations M3S (September 2000) and M16S (September 2001), respectively; and though the activity ratios were suggestive of reactor operations waste, insufficient data were available to conclusively establish the source of the plutonium. Some Pu-238 results are likely to be false positive (see caveat in Section 3.8).

Table 3-42. Plutonium-238 detections in samples collected from aquifer monitoring wells since 1997.

Plutonium-238 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3													0.044			
	4																
2000	1																
	2																
	3																
	4											0.37					
2001	1		0.018	0.030							0.019		0.028		0.071		
	2													0.17			
	3																
	4								0.034								

Table 3-42. (continued).

Plutonium-238 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3	0.047											0.102				
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis. For comparison, maximum contaminant level = 15 pCi/L total alpha.																	
	Analysis was performed, but Pu-238 was not detected.																
	Pu-238 was detected (pCi/L), but some reported results could be false positives (see caveat in Section 3.8).																
	Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.																

Table 3-43. Plutonium-239/240 detections in samples collected from aquifer monitoring wells since 1997.

Plutonium-239/240 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS- 127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																

Table 3-43. (continued).

Table 3-157 (continued).

Plutonium-239/240 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
2003	4																
	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3																
Note: The highest result is reported for duplicate samples or reanalysis.																	
For comparison, maximum contaminant level = 15 pCi/L (total alpha).																	
	Analysis was performed, but Pu-239/240 was not detected.																
	Pu-239/240 was detected (pCi/L).																
	Well is out of service. Well was rendered inoperable after repair attempts were unsuccessful.																

3.8.4 Summary of Plutonium

Plutonium-238 and Pu-239/240 were not detected in any soil moisture, perched water, or aquifer samples in FY 2005.

Historical detections in soil moisture and perched water are sporadic and generally characterized by low concentrations, typically 2 to 50 times below the MCL of 15 pCi/L (total alpha). However, a couple of instances have occurred where detections exhibit concentrations near (i.e., 11.6 pCi/L) and above (i.e., 24 pCi/L) the MCL of 15 pCi/L. In most cases, detections were not replicated or confirmed upon reanalysis, analysis of a duplicate sample, or subsequent sampling events.

Plutonium detections in RWMC aquifer samples are very rare and generally are characterized by very low concentrations (i.e., 0.018 to 1.3 pCi/L), typically one to three orders of magnitude below the MCL of 15 pCi/L. Of 1,131 sample analyses performed since 1997, only 15 positive detections were observed. Eleven of the 15 detections were not confirmed upon sample reanalysis, and four of the 15 were substantiated with positive reanalysis results. The four confirmed detections occurred in October 2000 and were associated with monitoring Wells M7S and M11S. Plutonium has not been detected in either of these monitoring wells since that time. Fifteen detections out of 1,131 sample analyses equals a detection frequency of 1.3% (for combined Pu-238 and Pu-239/240), which is essentially in the noise range. The noise range is effectively characterized by the detection rate associated with field blank samples (1.3% for combined Pu-238 and Pu-239/240 analyses).

Using state-of-the-art methods and detection instrumentation, it is concluded that plutonium is not present in the aquifer near RWMC at measurable concentrations. This conclusion is based on (1) a detection rate that is in the noise range and consistent with the detection rate of accompanying field blanks, (2) questionable validity of historical Pu-238 detections and the likelihood of detections being false positive, as determined by the anomalously high number of Pu-238 detections compared to Pu-239/240 detections, and (3) ultra-low levels of plutonium not being detected in the aquifer using IDTIMS analysis methodology (Roback 2003).

These data, including concentration ranges, detection frequencies, and MCL exceedances for Pu-238 and Pu-239/240 since 1997, are summarized in Tables 3-44 and 3-45, respectively.

Table 3-44. Concentration ranges, detection rates, and maximum contaminant level exceedances of plutonium-238 in sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone 0 to 35 ft)							
Soil moisture	3.8	7/185	1	PA03	0.9 ± 0.3	6.7 ± 1.1	24 ± 2
Vadose zone (35 to 140 ft)							
Soil moisture	1.9	3/155	0	None	3.1 ± 0.7	6.0 ± 1.0	11.6 ± 1.8
Vadose zone (140 to 250 ft)							
Soil moisture	0.7	1/136	0	None	NA	NA	4.8 ± 1.0
Vadose zone (>250 ft)							
Soil moisture	0.0	0/37	0	None	NA	NA	NA
Aquifer	2.3	13/567	0	None	0.018 ± 0.006	0.077 ± 0.006	0.37 ± 0.07
Aquifer field blanks	2.3	1/44	0	None	NA	NA	0.084 ± 0.019

Note: Some reported results for Pu-238 could be false positives (see caveat in Section 3.8).

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

Table 3-45. Concentration ranges, detection rates, and maximum contaminant level exceedances of plutonium-239/240 in sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone 0 to 35 ft)							
Soil moisture	0.5	1/186	0	None	NA	NA	0.70 ± 0.17
Vadose zone (35 to 140 ft)							
Soil moisture	1.9	3/155	0	None	0.34 ± 0.09	1.6 ± 0.5	3.3 ± 1.0
Vadose zone (140 to 250 ft)							
Soil moisture	0.8	1/133	0	None	NA	NA	2.7 ± 0.6
Vadose zone (>250 ft)							
Soil moisture	0.0	0/37	0	None	NA	NA	NA
Aquifer	0.4	2/564	0	None	0.034 ± 0.010	0.064 ± 0.003	0.09 ± 0.03
Aquifer field blanks	0.0	0/43	0	None	NA	NA	NA

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant limits for water).

3.9 Radium-226 and Radium-228

Radium-226 is a radioactive decay product in the naturally occurring uranium series. It decays by the emission of alpha particles and gamma rays and has a half-life of 1,600 years. In a 1,000-year interval, accounting for both decay of original inventories and ingrowth from members of the uranium series, approximately 42 Ci of Ra-226 would develop.

Though Ra-226 has been a targeted analyte in the past, it was removed from the aquifer and vadose zone gamma-emitting radionuclide target lists at the beginning of FY 2003 and 2004, respectively. Samples continue to be gamma-scanned; however, because Ra-226 is no longer targeted, the analytical laboratory only reports Ra-226 detections if concentrations exceed instrument and sample matrix background levels. Routine gamma analyses generally do not require that samples undergo a holding time to allow for ingrowth and equilibration of daughter products; however, this holding time is necessary for accurate quantification of Ra-226. Gamma analyses for Ra-226 provide adequate screening data, but results are not accurate enough for primary drinking water MCL-compliance purposes.

Radium-228 is a radioactive decay product in the naturally occurring thorium series. It decays by emission of beta particles and has a half-life of only 5.76 years. Waste buried in the SDA did not contain any known Ra-228 at the time of disposal; however, Ra-228 inventories will increase over time through ingrowth attributable to isotopes in the thorium series. Over a 1,000-year interval, approximately 3.48 Ci of Ra-228 is estimated to be produced. Radium-228 is not a target analyte; therefore, no monitoring data are available.

Radium-226 monitoring data for soil moisture, perched water, and aquifer are summarized in this section. Sampling data in this section are evaluated against comparison concentrations in Table 2-2.

3.9.1 Buried Waste Inventory

About 65.1 Ci of Ra-226 was buried in the SDA through 1999. An additional 0.19 Ci of Ra-226 is projected to be added by 2009, for a total of 65.3 Ci. The small inventories of Ra-226 in buried waste at the time of disposal are relatively insignificant. Radium-226 was identified as a contaminant of potential concern because additional quantities are being generated over time through ingrowth (Holdren et al.2006).

3.9.2 Vadose Zone

Vadose zone soil-moisture and perched water samples were not specifically collected or targeted for Ra-226 analyses in FY 2005; however, they were scanned for gamma-emitting radionuclides. Radium-226 is reported by the analytical laboratory only if it is detected above instrument or sample matrix background because it is no longer a targeted gamma-emitting radionuclide. Fiscal Year 2005 soil-moisture samples collected from each depth interval and analyzed by gamma spectrometry, including any detected Ra-226 results, are discussed in following subsections. Method detection limits historically encountered for soil-moisture samples, using gamma spectrometric analysis, are around 35 pCi/L, but can exceed a few hundred pCi/L when sample quantities are very small (i.e., 20 mL or less).

3.9.2.1 Lysimeter Samples at Depths 0 to 35 ft. In FY 2005, 36 gamma spectrometer analyses were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, with no Ra-226 detections reported above laboratory instrument or sample matrix background.

Historically, 147 Ra-226 analyses were performed by gamma spectrometry on soil-moisture samples collected from 18 lysimeters between 1997 and October 2003, with eight positive detections (see

Table 3-46). Detections were assigned data qualification flags because of recognized inaccuracies associated with the analytical method (see Section 3.9). Section 3.9.4 summarizes concentration ranges, detection rates, and MCL exceedances since monitoring began.

Table 3-46. Radium-226 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Radium-226 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)														
Year	Quarter	98-1: L35	98-4: L38	98-5: L39	PA01: L15	PA02: L16	PA03: L33	W06: L27	W08: L13	W08: L14	W23: L07	W23: L08	W23: L09	W25: L28
1997	1													
	2													
	3													
	4													
1998	1													
	2													
	3													
	4													
1999	1													
	2													
	3													
	4													
2000	1													
	2													
	3				34*									
	4													
2001	1													
	2			46*										
	3													
	4													
2002	1													
	2													
	3				50*						47*			
	4		73*											
2003	1													
	2													
	3													
	4													
Note: The highest result is reported for duplicate samples or reanalysis.														
* = concentration values may be inaccurate due to limitations or biases of the analytical method (see discussion in Section 3.9).														
For comparison, maximum contaminant level = 5 pCi/L														
	Ra-226 was analyzed but not detected.													
	Ra-226 was detected (pCi/L).													

3.9.2.2 Lysimeter Samples at Depths 35 to 140 ft. In FY 2005, 45 gamma spectrometer analyses were performed on soil-moisture samples collected from 16 shallow-depth lysimeters near RWMC, with no Ra-226 detections reported above laboratory instrument or sample matrix background.

Historically, 104 Ra-226 analyses were performed by gamma spectrometry on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC between April 1997 and October 2003, with one positive detection. The detection occurred in June 2000 at lysimeter location I-3S:DL13. The detected result ($2,020 \pm 607$ pCi/L) was assigned a data qualification flag because of recognized inaccuracies associated with the analytical method (see Section 3.9). Because only one detection occurred since monitoring began, a table presenting historical results is not presented; however, Section 3.9.4 presents concentration ranges, detection rates, and exceedances for Ra-226 since monitoring began.

3.9.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 73 gamma spectrometric analyses were performed on soil-moisture samples collected from 26 deep lysimeters and two perched water wells near RWMC, with no Ra-226 detections reported above laboratory instrument or sample matrix background.

Historically, 73 Ra-226 analyses were performed by gamma spectrometry on soil moisture and filtered sediment samples collected from 13 lysimeters and three perched water wells between 1997 and October 2003, with one positive detection. The detection occurred October 2002 in perched waster Well USGS-92. The detected result (43 ± 10 pCi/L) was assigned a data qualification flag because of recognized inaccuracies associated with the analytical method (see Section 3.9). Some filtered sediment samples showed positive indications of Ra-226, but the corresponding filtrate sample showed no detections. Because of the presence of natural Ra-226 and U-235, detections are likely in the filtered sediment samples. Because only one detection occurred since monitoring began, a table of historical results is not presented; however, Section 3.9.4 presents concentration ranges, detection rates, and exceedances for Ra-226 since monitoring began.

3.9.3 Aquifer

In FY 2005, 35 gamma spectrometric analyses were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, with no Ra-226 detections reported above laboratory instrument or sample matrix background.

Historically, 270 Ra-226 analyses were performed by gamma spectrometry on aquifer samples collected from 16 RWMC aquifer monitoring wells between April 1997 and November 2002, with two unqualified detections. The detections occurred in November 2002 in Wells M4D and USGS-127 (see Table 3-47). Detections are questionable because they are very near the method detection limit and barely exceed the 3σ detection criterion. Positive detections of Ra-226 were noted on 42 other sample results during this time frame (see Table 3-47); however, those detections were assigned data qualification flags because of recognized inaccuracies of the analytical method (see discussion in Section 3.9).

Section 3.9.4 presents concentration ranges, detection rates, and MCL exceedances of all results, including questionable results.

Table 3-47. Radium-226 detections in aquifer monitoring wells since 1997.

Radium-226 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Calendar Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	OW-2	A11 A31	USGS -127
1997	1																
	2																
	3																
	4																
1998	1	19*															
	2																
	3	17*															
	4			56*	13*		61*	54*	19*	40*	19*						
1999	1	14*		55*	11*		33*	50*	12*	36*	15*						
	2																
	3	14*		59*	11*		38*			33*	14*						
	4								8.7*								
2000	1																
	2																
	3																
	4																
2001	1									13*				31*			
	2													9.1*			
	3																
	4				18*			14*			11*						
2002	1							26*			8.1*		15*	12*		12*	14*
	2																
	3										10*						
	4			7.5													13
Note: The highest result is reported for duplicate samples or reanalysis.																	
* = indicates concentrations that may be inaccurate due to limitations or biases of the analytical method (see discussion in Section 3.9).																	
For comparison, maximum contaminant level = 5 pCi/L.																	
	Ra-226 was analyzed but not detected.																
	Ra-226 was detected (pCi/L).																
	Well is out of service. Well was rendered inoperable after repairs were unsuccessful.																

3.9.4 Summary of Radium-226

In FY 2005, no Ra-226 detections were reported above laboratory instrument or sample matrix background levels in lysimeter, perched water, and aquifer samples. Some detections in the aquifer near RWMC have concentrations greater than background levels; however, these detections are due to the bias in the analytical method. Table 3-48 summarizes concentration ranges, detection frequencies, and MCL exceedances since 1997.

Table 3-48. Radium-226 concentration ranges and detection frequencies greater than background levels in sampled media.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentrations	Range of Detected Concentrations ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone 0 to 35 ft)								
Soil moisture	4.0	8/199	8	98-4, 98-5, PA01, W06, W08, W23	33 ± 9 _J	52 ± 13	73 ± 20 _J	
Vadose zone (35 to 140 ft)								
Soil moisture	0.6	1/178	1	I-3S	NA	NA	2020 ± 607 _J	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	0.7	1/151	1	USGS-92	NA	NA	43 ± 10 _J	
Vadose zone (>250 ft)								
Soil moisture	0.0	0/39	0	None	NA	NA	NA	
Aquifer								
	11.0	44/399	44	M1S, M4D, M6S, M10S, M11S, M12S, M13S, M14S, M16S, M17S, A11A31, USGS-127	8 ± 2	23 ± 4	61 ± 7 _J	
Aquifer field blanks								
	5.6	1/18	1	NA	NA	NA	279 ± 35	

a. Ratio = number of detections above background concentrations/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

c. Concentrations may be inaccurate due to limitations or biases of the analytical method (see discussion in Section 3.9).

3.10 Strontium-90

Strontium-90 is a radioisotope generated by nuclear reactor operations. Strontium-90 is a fission product that decays by the emission of beta particles with a half-life of 28.8 years.

The following sections summarize available information about Sr-90 monitoring data for all media. Sampling data in this section were evaluated against comparison concentrations in Table 2-2.

3.10.1 Buried Waste Inventory

Approximately $1.36\text{E}+05$ Ci of Sr-90 was buried in the SDA through 1999, and an additional $1.09\text{E}+02$ Ci is projected to be added by 2009, for a total of $1.36\text{E}+05$ Ci. The Remedial Investigation and Baseline Risk Assessment (Holdren et al. 2006) identifies waste streams containing most of the Sr-90 activity. The primary source of Sr-90 in the SDA is INL Site reactor operations waste and subassembly hardware. Strontium-90 also is of interest to the ongoing LLW disposal operation in the SDA and has an action level of 8 pCi/L in the aquifer (Parsons, Seitz, and Keck 2005).

3.10.2 Vadose Zone

The following subsections discuss distribution of Sr-90 in vadose zone soil moisture and perched water in shallow-, intermediate-, and deep-depth intervals. The number of sample analyses for Sr-90 is small because lysimeter sample volumes are often limited, and other radionuclides have precedence. Also, Sr-90 is a surface exposure pathway risk driver and, therefore, not a priority analyte in the vadose zone.

3.10.2.1 Lysimeter Well Samples at Depths from 0 to 35 ft. In FY 2005, nine analyses for Sr-90 were performed on soil-moisture samples collected from nine shallow-depth lysimeters near RWMC, with no positive detections.

Since 1997, 82 analyses for Sr-90 were performed on shallow-depth lysimeter samples, with eight positive detections ranging in concentration from 2.2 to 52 pCi/L. Table 3-49 summarizes historical data for Sr-90 in shallow-depth vadose zone samples, since routine monitoring began in 1997. As shown in Table 3-49, detections are sporadic, with no apparent trends or spatial pattern. Positive sample results were not confirmed by reanalysis of original samples. The 52-pCi/L result obtained in Well W06-L27 was not confirmed by reanalysis, and Sr-90 was not detected in that lysimeter in the five sampling events subsequent to that detection. Section 3.10.4 presents these data including concentration ranges, detections rates, and MCL exceedances since 1997.

3.10.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 10 analyses for Sr-90 were performed on soil-moisture samples collected from 10 intermediate-depth lysimeters near RWMC, with no positive detections.

Historically, 24 Sr-90 analyses have been performed on soil-moisture samples collected from 12 lysimeters near RWMC since 1997, with one positive detection. The detection (4.1 ± 1.1 pCi/L) occurred at location TW1:DL04 in November 1998, and could not be confirmed by reanalysis because of the limited sample volume available. No other positive detections of Sr-90 have occurred in any lysimeters or perched water wells from this depth range since sample collection began in 1997. Though no table is presented showing historical data, Section 3.10.4 summarizes concentration ranges, detection rates, and exceedances since 1997.

Table 3-49. Strontium-90 occurrences in shallow-depth (0 to 35 ft) lysimeters from 1997.

Strontium-90 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																		
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																	
	2																	
	3																	
	4																	
1998	1																	
	2																	
	3																	
	4																	
1999	1																	
	2																	
	3																	
	4																	
2000	1																	
	2																	
	3																	
	4																	
2001	1																	
	2																	
	3																	
	4																	
2002	1-4																	
2003	1-4																	
2004	1-4																	
2005	1																	
	2																	
	3																	
	4																	
Note: The highest result is reported for duplicate samples or reanalysis.																		
For comparison, maximum contaminant level = 8 pCi/L.																		
		Analysis was performed, but Sr-90 was not detected.																
		Sr-90 was detected (pCi/L).																

3.10.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 12 analyses for Sr-90 were performed on 11 soil-moisture and one perched water well samples, with two positive detections (see Table 3-50). The detection in Well USGS-92 is the first to occur at this location in more than 25 years, and the detection at location R1935:DL58 is also a first occurrence. Therefore, surmising that a Sr-90 problem may be developing is premature. Section 3.10.4 summarizes concentration ranges, detection frequencies, and exceedances for FY 2005.

Table 3-50. Strontium-90 detections in deep (greater than 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Strontium-90	08/10/05	R1935:DL58	217.5	5.3 ± 0.8	2.4	8
	08/10/05	USGS-92	214	7.4 ± 1.1	3.4	

a. The maximum contaminant level is from the "National Primary Drinking Water Standards" (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Historically, 27 Sr-90 analyses have been performed on soil-moisture samples collected from 11 lysimeters and three perched water wells near RWMC since 1997, with two detections occurring in FY 2005 (discussed in previous paragraph). In addition, 10 filtered-sediment samples were analyzed during this time, with no positive detections. Because Sr-90 was not detected previously in this depth range, a table showing occurrences is not presented. Section 3.10.4 summarizes concentration ranges, detection rates, and exceedances between 1997 and 2005.

3.10.3 Aquifer

Strontium-90 analyses are performed on aquifer samples when the gross beta screening analysis results are higher than 5 pCi/L. In FY 2005, 35 screening analyses were performed on samples from 15 RWMC aquifer monitoring wells; only the result from Well M4D exceeded the screening limit. Consequently, Sr-90 analyses were performed, with no positive detection. Gross beta activity in Well M4D is consistently above the screening limit, and concentrations are about six times higher than all other RWMC aquifer monitoring wells. The gross beta activity is attributed to elevated concentrations of K-40 at this monitoring location. Section 3.10.4 summarizes concentration ranges, detection frequencies, and exceedances for FY 2005.

Historically, 384 gross beta screening analyses and 79Sr-90 analyses have been performed on 16 RWMC aquifer monitoring wells since 1997, with two positive Sr-90 detections. Both detections occurred in Well M4D in April 1997 at concentrations of 0.12 ± 0.02 and 0.17 ± 0.03 pCi/L. Because no other positive detections of Sr-90 have occurred, a table showing occurrences is not presented. Concentration ranges, detection rates, and exceedances between 1997 and 2005 are presented in Section 3.10.4.

3.10.4 Summary of Strontium-90

Data from lysimeter, perched water, and aquifer well samples do not indicate a widespread presence of Sr-90 in the environment of RWMC at levels exceeding background concentrations. No detectable concentration of Sr-90 has been found in aquifer monitoring wells since 1997. Detections in the vadose zone and aquifer monitoring wells show no apparent trends and no evident spatial distribution pattern. Table 3-51 summarizes concentration ranges, detection rates, and exceedances in FY 2005, while Table 3-52 summarizes those measured between 1997 and 2005.

Table 3-51. Concentration ranges and detection frequencies of strontium-90 in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	0.0	0/9	0	None	NA	NA	NA
Vadose zone (35 to 140 ft)							
Soil moisture	0.0	0/10	0	None	NA	NA	NA
Vadose zone (140 to 250 ft)							
Soil moisture	28.6	2/7	0	None	5.3 ± 0.8	6.4 ± 1.0	7.4 ± 1.1
Vadose zone (>250 ft)							
Soil moisture	0.0	0/5	0	None	NA	NA	NA
Aquifer	0.0	0/1	0	None	NA	NA	NA
Aquifer field blanks	0.0	0/0	0	None	NA	NA	NA

a. Ratio = number of detections/number of sample analyses

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant limits for water).

Table 3-52. Concentration ranges, detection rates, and exceedances of strontium-90 in sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentrations	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	8.5	7/82	2	PA02, W06	2.2 ± 0.7	11.1 ± 1.5	52 ± 4
Vadose zone (35 to 140 ft)							
Soil moisture	4.2	1/24	0	None	NA	NA	4.1 ± 1.2
Vadose zone (140 to 250 ft)							
Soil moisture	9.1	2/22	0	None	5.3 ± 0.8	6.4 ± 1.0	7.4 ± 1.1
Vadose zone (>250 ft)							
Soil moisture	0.0	0/5	0	None	NA	NA	NA
Aquifer	2.5	2/79	0	None	0.12 ± 0.02	0.93 ± 0.22	2.5 ± 0.6
Aquifer field blanks	0.0	0/0	0	None	NA	NA	NA

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

3.11 Technetium-99

Technetium-99 is a fission product generated primarily by nuclear reactor operations. It decays by emission of beta particles and low-energy gamma rays and has a half-life of 2.13E+05 years.

Technetium can be very mobile once released and has been detected in samples from vadose zone lysimeters, perched water, and aquifer monitoring wells. The following subsections summarize Tc-99 monitoring data for all media. Sampling data in this section are evaluated against comparison concentrations in Table 2-2.

3.11.1 Buried Waste Inventory

Approximately 40.2 Ci of Tc-99 was buried in the SDA through 1999, and an additional 2.09 Ci is projected to be added by 2009, for a total of 42.3 Ci. The primary source of Tc-99 in the SDA is operations waste and subassembly hardware from INL Site reactors (Holdren et al. 2006).

3.11.2 Vadose Zone

This section discusses distribution of Tc-99 in vadose zone soil moisture and perched water in the targeted depth intervals.

3.11.2.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 36 analyses for Tc-99 were performed on soil-moisture samples collected from 14 shallow-depth lysimeters near RWMC, with one positive detection (see Table 3-53). Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances, as well as the locations where Tc-99 was detected in FY 2005.

In FY 2005, four other positive detections were identified in this depth interval; however, the results are not listed in Table 3-53 because they contain “UJ” analytical method data validation flags, which strongly discourage using the data. The samples were from lysimeter Wells 98 1, 98 4, PA01, and PA02, where Tc-99 has been detected previously. The assigned data validation flags are considered to be too limiting and restrictive because of the basis for the flags: a minor amount of Tc-99 was statistically detected in the laboratory matrix blank. Other laboratory quality control tests, including tests performed on the field blank sample, met data quality requirements. Therefore, the project recognizes these results as positive detections and considers the data useable as a qualitative indicator of the possible presence of Tc-99 at these locations in the shallow vadose zone.

Table 3-53. Technetium-99 detections in shallow-depth (0 to 35 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Technetium-99	05/25/05	98-1:L35	16.5	38 ± 8	30	900

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Between 1997 and August 2005, 178 analyses for Tc-99 were performed on soil-moisture samples collected from 18 shallow-depth lysimeters; these analyses resulted in 28 positive detections, with concentrations ranging from 13 to 68 pCi/L (see Table 3-54). Detected concentrations were below the MCL of 900 pCi/L, and no trends are evident in the shallow-depth interval. Most historical detections in the 0 to 11-m (0 to 35-ft) region of the vadose zone are from lysimeter wells located around Pad A (i.e., Wells PA01, PA02, and PA03) and the western part of the SDA (i.e., Wells 98-4, 98 5, W23, and W25). Section 3.11.4 presents these data including concentration ranges, detection rates, and exceedances since 1997.

Because disposal records do not indicate significant quantities of Tc-99 on or near Pad A, analytical data showing Tc-99 beneath Pad A could infer that topographic features in the subsurface are channeling leachate toward the region beneath Pad A. Alternatively, trace amounts of Tc-99 in uranium waste on Pad A could be the source (ICP 2005).

Monitoring Well W23 contains three lysimeters at approximate depths of 2.4, 3.7, and 5.8 m (8, 12, and 19 ft), and Tc-99 has been detected at all three depths. Eight of 13 results from Lysimeter W23:L09 (i.e., 2.4 m [8 ft] deep) contained detectable amounts of Tc-99. In 1998, 2000, and 2001, Tc-99 was detected at 3.7 m (12 ft) (i.e., Lysimeter W23:L08), and in 2002, it was detected at 5.8 m (19 ft) (i.e., Lysimeter W23:L07). The progression of detections at different depths over time suggests that migration in the vadose zone may be occurring. In FY 2005, Tc-99 was not detected at Lysimeters W23:L07 and W23:L09; this may imply that Tc-99 has migrated past Well W23 monitoring locations to deeper regions.

Table 3-54. Technetium-99 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Technetium-99 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS1: L41	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																				
	2																				
	3																			17	
	4																			30	
1998	1																				
	2																				
	3																				
	4																		15*	20	
1999	1						39*	13	36												
	2																				
	3																				
	4																				
2000	1								21												
	2								17											20	
	3	16		21			17								15				39	33	
	4						27														
2001	1																				
	2																				
	3																		46		
	4																				
2002	1																				
	2																				
	3																				
	4																			15*	

Table 3-54. (continued).

Table 3-5-4 (Continued):

Technetium-99																					
Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																					
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS1: L41	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2003	1		28*	34*	22*													68*			25*
	2																				
	3																				
	4																			42	
2004	1			19																	
	2																				
	3																			35*	
	4																				
2005	1																				
	2	X	X				X	X													
	3	38																			
	4																				
Note: The highest result is reported for duplicate samples or reanalysis.																					
* = indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.																					
X = indicates positive detections with data limitations and restrictions (see discussion in Section 3.11.2.1); however, data provide a qualitative indicator of the possible presence of Tc-99 at these locations.																					
For comparison, maximum contaminant level = 900 pCi/L.																					
	Analysis was performed, but Tc-99 was not detected.																				
	Tc-99 was detected (pCi/L.)																				

3.11.2.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 44 analyses for Tc-99 were performed on soil-moisture samples collected from 16 intermediate-depth lysimeters near RWMC, resulting in three positive detections (see Table 3-55). Technetium-99 detections at lysimeter locations D06:DL01 and D06:DL02 are relatively common occurrences; approximately 70% of samples from DL01 and 30% of samples from DL02 are positive. The detection at location R2004:DL50 is the first sample to be collected from this lysimeter since the monitoring well was installed in 2004, so no previous data are available for comparison. Data from this location will continue to be monitored. Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances as well as sampling locations where Tc-99 was detected in FY 2005.

Table 3-55. Technetium-99 detections in intermediate-depth (35 to 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Technetium-99	11/15/04	D06:DL01	88	111 ± 11	31	900
	11/15/04	D06:DL02	44	70 ± 10	30	
	05/25/05	R2004:DL50	74	872 ± 18	33	

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Table 3-56 summarizes historical data for Tc-99 in intermediate-depth vadose zone samples, since routine monitoring began in 1997. The 157 analyses performed in this depth interval have resulted in 23 positive detections, with concentrations ranging from 5.8 to 1,480 pCi/L. Most historical detections at this depth are from lysimeter wells located near Pad A (i.e., D06, PA03) and the western part of the SDA (i.e., I1S, I2S, and D15). Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances since 1997.

Monitoring Well D06 contains two lysimeters at depths of 13.4 and 27 m (44 and 88 ft), and Tc-99 has been frequently detected at both depths. At Lysimeter D06:DL01 (i.e., 13.4 [44 ft]), the concentration decreased steadily between 1998 and 2003; however, an unexplained concentration spike occurred in May 2004. Subsequent sampling in 2005 show the concentrations have decreased to levels measured prior to the spike in May 2004 (see Figure 3-10). The concentration at 27 m (88 ft) (D06:DL02) remained constant between 1998 and 2002. Between 2003 and the end of 2004, the concentration increased at a fairly substantial rate, then decreased suddenly and unexpectedly in May 2005. Since that time, concentrations have remained low (see Figure 3-10). The progression of detections and concentration changes over time at these two locations suggests that Tc-99 may be migrating in the vadose zone. Technetium-99 was not detected at locations DL01 or DL02 the last two quarters of FY 2005, possibly suggesting Tc-99 has migrated past these two monitoring locations and moved to deeper depths. Continued monitoring will help determine the pattern and location of Tc-99 contamination in this region of the vadose zone.

Table 3-56. Technetium-99 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Technetium-99 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																		
	2																		
	3																		
	4																		
1998	1																		
	2																		
	3																		
	4	11	33																
1999	1																		
	2																		
	3																		
	4																		
2000	1																		
	2																		
	3																		
	4																		
2001	1																		
	2																		
	3																		
	4																		
2002	1																		
	2																		
	3																		
	4																		

Table 3-56. (continued).

Technetium-99 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2003	1	13		28*	29*	25*	18*							20*					
	2																		
	3	34																	
	4	61																	
2004	1	40			32									1480					22
	2																		
	3	90	197																
	4																		
2005	1	111	70																
	2																		
	3																872		
	4																		
Note: The highest result is reported for duplicate samples or reanalysis.																			
* = indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																			
For comparison, maximum contaminant level = 900 pCi/L.																			
	Analysis was performed, but Tc-99 was not detected.																		
	Tc-99 was detected (pCi/L).																		

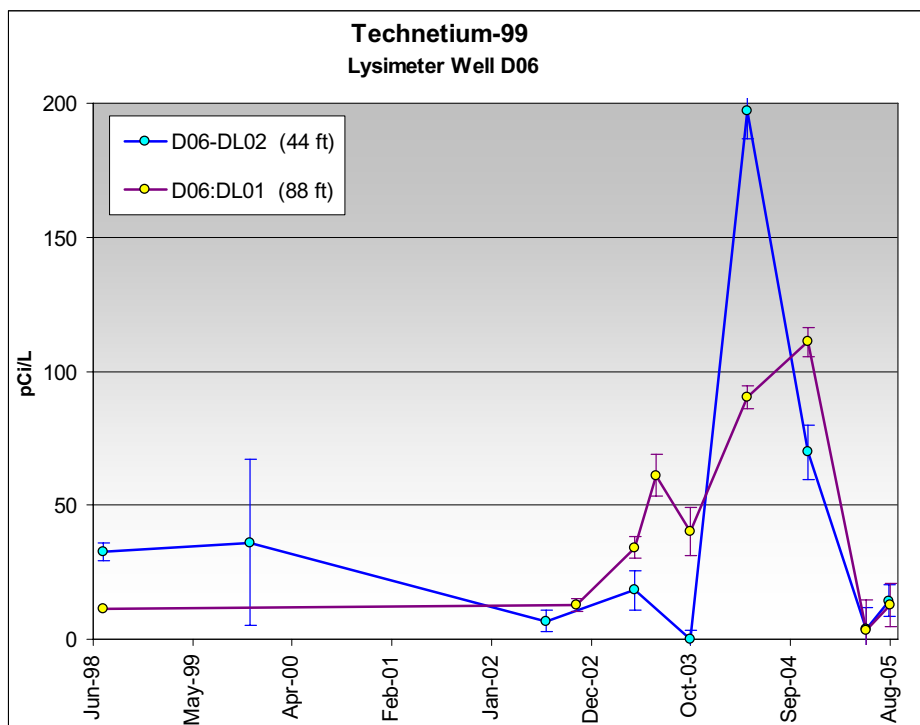


Figure 3-10. Technetium-99 concentration history for Lysimeters D06:DL01 and D06:DL02.

3.11.2.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In

FY 2005, 73 analyses for Tc-99 performed on samples collected from 26 lysimeters and two perched water wells near RWMC resulted in one positive detection (see Table 3-57). The detected concentration was less than the MCL used for comparison. Technetium-99 was not detected in prior or subsequent sampling events; thus, at present, the detection appears to be a one-time occurrence.

In FY 2005, two other positive detections were identified in this depth interval; however, the results are not listed in Table 3-57 because they contain “UJ” analytical method data validation flags, which strongly discourage using the data. The samples were from Lysimeter R1936:DL62 and perched water Well USGS-92. Technetium-99 was detected previously in USGS-92, but has not been detected at location R1936:DL62. However, Tc-99 was detected in Lysimeter R1936:DL63, which is located in the same monitoring well and positioned 12 m (40 ft) above Lysimeter R1936:DL62. The assigned data validation flags are considered to be too limiting and restrictive because of the basis for the flags: a minor amount of Tc-99 was statistically detected in the laboratory matrix blank. Other laboratory quality control tests, including tests performed on the field blank sample, met data quality requirements. These results are recognized as positive detections, and the data are considered usable as a qualitative indicator of the possible presence of Tc-99 at these locations in the intermediate-depth vadose zone. Data at these locations will continue to be monitored. Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances as well as sampling locations where Tc-99 was detected in FY 2005.

Table 3-57. Technetium-99 detections in deep (greater than 140 ft) lysimeters in Fiscal Year 2005.

Radionuclide	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration
						Maximum Contaminant Level ^a (pCi/L)
Technetium-99	02/05/05	R1936:DL63	302	61 ± 10 _J ^b	30	900

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

b. Concentration value with the “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the Tc-99 result because a statistically positive amount of Tc-99 was detected in the method blank. The result is questionable but usable, but should only be used as an estimated quantity.

Table 3-58 summarizes historical data for Tc-99 in the deep vadose zone samples since 1997. The 183 analyses performed in this depth interval resulted in 11 positive detections, with concentrations ranging from 17 to 280 pCi/L. Six of the detections occurred in samples from wells inside the SDA, and five detections were associated with samples collected outside the SDA. Detecting Tc-99 in wells outside the SDA (i.e., Wells O2, O4, O6, and O7 in October 2002, and Well R1936 in February 2005) was unexpected and could not be explained; however, no detections have occurred in these outside wells since then. Of the five wells inside the SDA with positive detections, only perched water Well USGS-92 has had multiple detections, the last being July 2003. Detection rates at the different monitoring depth intervals show that Tc-99 has not moved deeper than 140 ft. Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances since 1997.

Table 3-58. Technetium-99 detections in deep (greater than 140 ft) lysimeters and perched water since 1997.

Technetium-99																																			
Radioactive Waste Management Complex Perched Water and Lysimeters (greater than 140 ft)																																			
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	R2004: DL48	R2006: DL43	S1898: DL40	USGS-092	
1997	1																																		
	2																																		
	3																																		
	4																																		
1998	1																																		
	2																																		
	3																																		
	4																																		
1999	1																																		28*
	2																																		
	3																																		
	4																																		
2000	1																																		
	2																																		
	3																																		
	4																																		280
2001	1																																		
	2																																		
	3																																		
	4																																		
2002	1																																		
	2																																		
	3																																		
	4																																		
2003	1														31		37	18*	29*																
	2																																		
	3																																		
	4																																		28
2004	1				19									17																					
	2																																		
	3										41																								
	4																																		
2005	1																																		
	2																										X	61							X
	3																																		
	4																																		
Note: The highest result is reported for duplicate samples or reanalysis.																																			
* = indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.																																			
X = indicates positive detections with data limitations and restrictions (see discussion in Section 3.11.2.3); however, the data provide a qualitative indicator of the possible presence of Tc-99 at these locations.																																			
For comparison, maximum contaminant level = 900 pCi/L.																																			
	Analysis was performed for Tc-99, but none was detected.																																		
	Tc-99 was detected (pCi/L).																																		

3.11.3 Aquifer

In FY 2005, 35 analyses for Tc-99 were performed on aquifer samples collected from 15 aquifer monitoring wells near RWMC, with one positive detection (see Table 3-59). The detection was associated with Well M16S, where Tc-99 has never been detected before, and the measured concentration was low, just barely exceeding the method detection limit. Section 3.11.4 summarizes concentration ranges, detection frequencies, and exceedances for FY 2005.

Table 3-59. Technetium-99 detections in aquifer samples in Fiscal Year 2005.

Radionuclide	Sample Date	Well	Sample Result (pCi/L)	Minimum Detectable Concentration (pCi/L)	Comparison Concentration Maximum Contaminant Level ^a (pCi/L)
Technetium-99	05/04/05	M16S	1.6 ± 0.4	1.4	900

a. The maximum contaminant level is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

Since 1997, 403 analyses for Tc-99 were performed on aquifer well samples collected from 16 monitoring wells near RWMC and resulting in six positive detections (see Table 3-60). Detected concentrations ranged from 1 to 35 pCi/L. None of the positive results exceeded the MCL of 900 pCi/L. Only the May 2000 detection of Tc-99 for Well M17S was confirmed by reanalysis of the original sample; however, the positive result did not agree with the original analysis. Subsequent samples collected from these aquifer monitoring wells have not yielded positive detections.

Table 3-60. Technetium-99 detections in aquifer monitoring wells since 1997.

Technetium-99 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3											1.4		1.0			
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3									35							
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2														1.2		
	3																
	4																

Table 3-60. (continued).

Technetium-99 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	A11A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
2005	1																
	3							1	1.6								
Note: The highest result is reported for duplicate samples or reanalysis.																	
For comparison, maximum contaminant level = 900 pCi/L.																	
		Analysis was performed, but Tc-99 was not detected.															
		Tc-99 was detected (pCi/L).															
		Well is out of service. Well was rendered inoperable after repairs were unsuccessful.															

3.11.4 Summary of Technetium-99

Technetium-99 is frequently detected in soil-moisture samples collected in the 0 to 35-ft and 35 to 40-ft depth intervals and is intermittently detected in the 140 to 250-ft region. Soil-moisture concentrations generally range from about 6 to 900 pCi/L, with a mean value around 50 pCi/L; however, one anomalous result reached 1,480 pCi/L. Technetium-99 contamination in the vadose zone does not appear to be widespread; rather, it appears more prevalent around Pad A and the western end of the SDA.

Historically, lysimeter wells with the most frequent and consistent detections of Tc-99 are Lysimeter Wells D06 and W23 (see detection rate in Table 3-61). These wells are located in areas of the SDA where no Tc-99 disposals are noted. The only commonalities between these two wells are that, in addition to the presence of Tc-99, uranium concentrations are significantly greater than background. Figure 3-11 shows sampling locations where Tc-99 was detected in the SDA in FY 2005, and Table 3-62 summarizes concentration ranges, detection frequencies, and exceedances for all sample media in FY 2005. Table 3-61 lists historical concentration ranges, detection frequencies, and exceedances.

Detections of Tc-99 occur sporadically in the aquifer and are not indicative of trends or widespread contamination.

Table 3-61. Concentration ranges and detection frequencies of technetium-99 in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	2.8	1/36	0	None	NA	NA	38 ± 8
Vadose zone (35 to 140 ft)							
Soil moisture	6.8	3/44	0	None	70 ± 10	351 ± 13	872 ± 18
Vadose zone (140 to 250 ft)							
Soil moisture	0.0	0/47	0	None	NA	NA	NA
Vadose zone (>250 ft)							
Soil moisture	3.8	1/26	0	None	NA	NA	61 ± 10
Aquifer	0.0	1/35	0	None	NA	NA	1.6 ± 0.4
Aquifer field blanks	0.0	0/2	0	None	NA	NA	NA

a. Ratio = number of detections/number of sample analyses

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant limits for water).

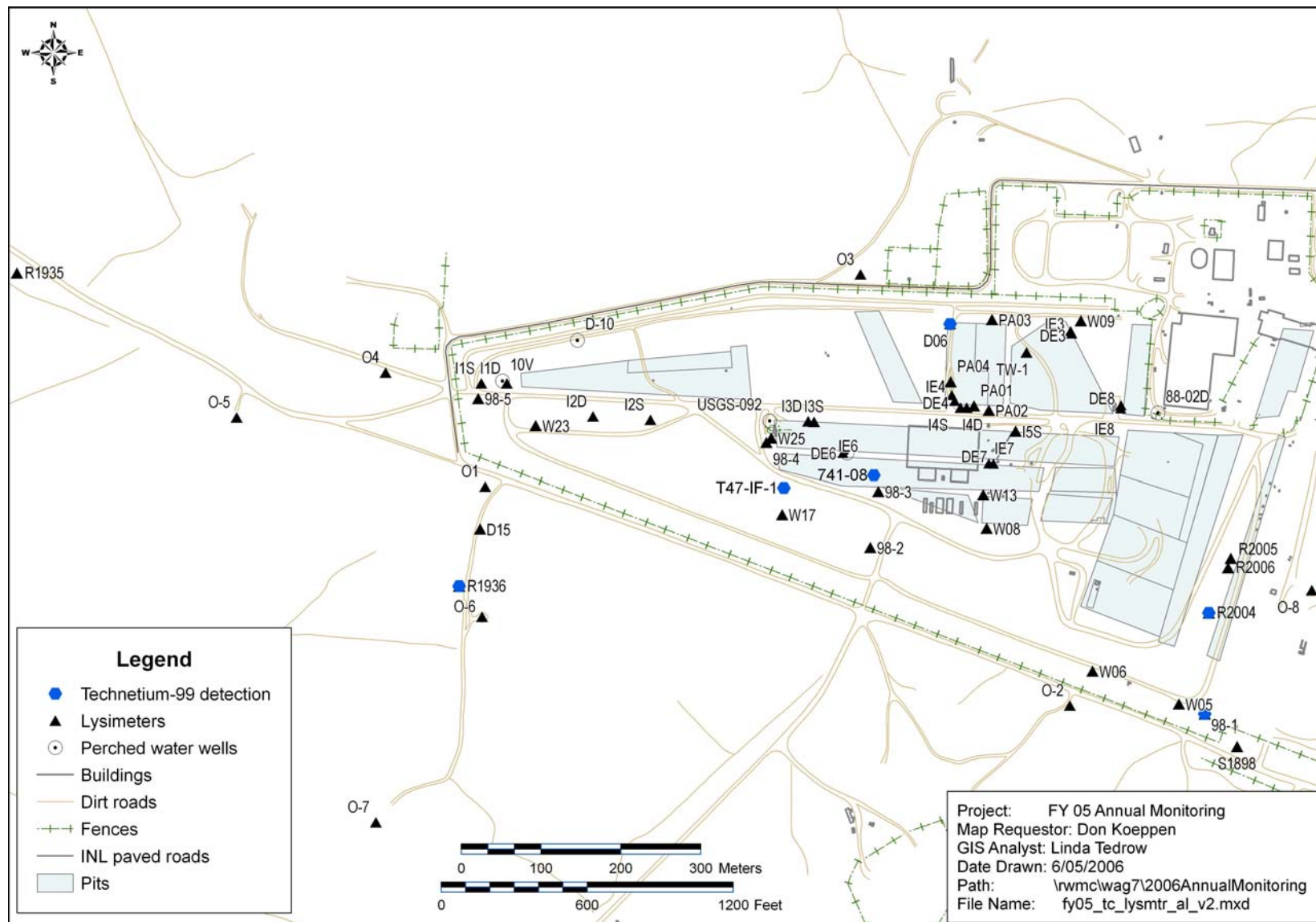


Figure 3-11. Technetium-99 detection locations in Fiscal Year 2005.

Table 3-62. Concentration ranges, detection rates, and maximum contaminant level exceedances of technetium-99 in sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentrations	Range of Detected Concentrations (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	15.7	28/178	0	None	13 ± 3	27 ± 5	68 ± 6
Vadose zone (35 to 140 ft)							
Soil moisture	14.6	23/157	1	O7S	5.8 ± 1.3	142 ± 8	1480 ± 28
Vadose zone (140 to 250 ft)							
Soil moisture and perched water	6.3	9/144	0	None	17 ± 5	57 ± 10	280 ± 37
Vadose zone (>250 ft)							
Soil moisture	5.1	2/39	0	None	19 ± 5	40 ± 7	61 ± 10
Aquifer	1.5	6/403	0	None	1.0 ± 0.3	7.0 ± 1.1	35 ± 5
Aquifer field blanks	7.4	2/27	0	None	0.34 ± 0.10	2.1 ± 0.3	4.9 ± 0.5

a. Ratio = number of detections/number of sample analyses.

b. Table 2-2 provides comparison concentrations (e.g., maximum contaminant levels for water).

3.12 Uranium-233/234, Uranium-235/236, and Uranium-238

Uranium is a radioactive element that occurs naturally in the environment, principally as U-238 with trace quantities of U-234 and U-235. Uranium also is used in nuclear weapons and nuclear reactors. Waste generated by these activities typically contains four principal uranium isotopes: U-234, U-235, U-236, and U-238. A fifth uranium isotope in waste, U-233, is produced in small quantities from decay of Am-241 and in significant quantities in nuclear reactors that use thorium fuel. Uranium-233, U-234, U-235, U-236, and U-238 all decay by emitting alpha particles and gamma rays, and have half-lives of 1.59E+05, 2.46E+05, 7.04E+08, 2.34E+07, and 4.47E+09 years, respectively.

Naturally occurring uranium coexists with anthropogenic sources in and near the SDA. To assess nature and extent of anthropogenic uranium contamination, background uranium in the environment must be differentiated from that introduced by waste disposal. The amount of uranium in the environment varies significantly around the globe, including Idaho and the INL Site. Background concentrations are established for U-234 and U-238 in surficial soil (Rood, Harris, and White 1996) and for total uranium in the Snake River Plain Aquifer (Knobel, Orr, and Cecil 1992), and the aquifer at the INL Site (Roback et al. 2001). Background concentration ranges and upper limits for evaluating uranium isotopes in vadose zone soil moisture (pore water) and in the aquifer at RWMC are defined using monitoring data from various sources, including those from USGS. Determination and application of uranium background are in discussed Section 3.12.1.2.

Anthropogenic uranium can be discriminated from naturally occurring uranium by assessing isotopic ratios. Table 3-63 presents typical isotopic ratios in natural and anthropogenic materials. Table 3-64 lists common isotopic compositions associated with enriched, depleted, and natural uranium. Enriched uranium refers to uranium ore that has been processed to increase the concentration of U-235. The by-product of the enrichment process, which contains increased concentrations of U-238, is referred to as depleted uranium.

Table 3-63. Radioactivity ratios for evaluating uranium data.

Type of Uranium	U-235 Present (wt%)	U-234:U-238 Ratio	U-238:U-235 Ratio
Depleted	0.2	~0.1	~78
Natural in earth's crust	0.7	~1 ^a	~22
Natural in INL Site groundwater	0.7	~1.5 to 3 ^b	~22
Low enrichment	3	~6	~5
High enrichment	93	~3,300	~0.01

Note: Ratios for depleted uranium and enriched uranium were obtained from Rocky Flats Plant and "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities" (DOE-STD-1136-2004, 2004).

a. Secular equilibrium conditions.

b. Disequilibrium—characteristic of Idaho National Laboratory groundwater and vadose zone soil moisture.

Table 3-64. Typical isotopic composition of anthropogenic uranium.

Form of Uranium	U-234 (wt%)	U-235 (wt%)	U-236 (wt%)	U-238 (wt%)
Enriched (high)	1.00	93.10	0.40	5.50
Enriched (low)	0.03	2.97	0.00	97.00
Depleted	0.001	0.22	0.00	99.78

Concentrations of uranium isotopes in monitoring samples generally are reported by the laboratory as U-233/234 (or U-233+234), U-235/236 (or U-235+236), and U-238. Pairs of isotopes are combined because they cannot be chemically separated, and they have nearly identical alpha particle energies. Therefore, isotopic pairs are almost impossible to differentiate in environmental-level samples using routine alpha spectroscopy. More sensitive, nonroutine analysis (i.e., mass spectrometry) is required to obtain results for each separate isotope or to determine accurate isotopic ratios. The following subsections describe methodology used to interpret uranium monitoring data at the SDA and summarize available uranium monitoring data for all media.

3.12.1 Methodology for Interpreting Uranium Monitoring Data

Methodology for interpreting uranium monitoring data involves evaluating isotopic ratios and discriminating background concentrations from anthropogenic uranium. Recent changes to methodology for evaluating isotopic ratios and background concentrations are summarized in subsections that follow.

3.12.1.1 Isotopic Uranium Ratios for Evaluating Uranium Analyses Data. Activity ratios of U-238:U-235 and U-234:U-238 are used to distinguish natural uranium from anthropogenic uranium and to estimate the amount of U-235 enrichment in anthropogenic uranium. Historically, detected U-238:U-235 ratios at six vadose zone monitoring locations and one aquifer well showed changes and trends interpreted as indicating the presence of anthropogenic uranium slightly enriched with U-235 (Olson et al. 2003; Koeppen et al. 2004). Trends in U-238:U-235 ratios were caused solely by changes in U-235 concentrations (i.e., U-238 concentrations were relatively constant while U-235 concentrations fluctuated). Though U-238:U-235 ratios were changing at these locations, U-234:U-238 ratios remained constant, which is unusual for anthropogenic uranium. Lack of correlation indicates that historical U-238:U-235 ratios are ambiguous, raising substantial doubt about previous conclusions that anthropogenic uranium was present. In response, the analytical and assessment process for evaluating isotopic uranium data was carefully reviewed, reaching the following conclusions about historical interpretations:

- Trends in U-238:U-235 isotopic ratios are not consistent and do not correlate with expected ratios and trends for U-234:U-238
- Inductively coupled plasma-mass spectrometry (ICPMS) analyses in November 2004 indicate previous assessments using U-238:U-235 activity ratios may be inaccurate
- Review of process indicators used to characterize low- and mid-level detections of uranium (i.e., measured concentrations, measurement uncertainties, isotopic ratios, background sample locations, and background concentration values) lack the robustness necessary for accurate characterization

- Activity ratios for U-238:U-235 obtained by routine analysis (alpha spectrometry) are inaccurate because of high uncertainties associated with low-level U-235 measurements
- All previous interpretations based on uranium activity ratios obtained by routine analysis should be discarded.

Uranium-235 is the most difficult uranium isotope to quantify accurately by alpha spectrometry because of its low activity in most environmental water samples (e.g., soil pore water, perched water, and aquifer samples). Historically, U-235 concentrations in most environmental water samples were too low to obtain reliable measurements using traditional radioanalytical methods (e.g., alpha spectrometry). Because routine monitoring requires isotopic uranium analysis using alpha spectrometry, U-235 and calculated U-238:U-235 activity ratios have relatively large uncertainties, especially at low concentrations. At locations in the SDA where uranium concentrations were high relative to other locations, U-238:U-235 activity ratios were used to tentatively identify the origin (i.e., natural or anthropogenic) and enrichment (i.e., if anthropogenic, whether from weapons production or reactor operations) of uranium.

In November 2004, samples from four wells previously suspected of containing anthropogenic uranium with a slight U-235 enrichment (i.e., D06:DL01, D06:DL02, PA01:L15, and TW1:DL04) were analyzed by ICPMS at the RTC analytical laboratory. This analytical methodology can detect extremely low concentrations of uranium isotopes with very high precision. Table 3-65 provides ICPMS results along with monitoring results obtained by less-sensitive, routine alpha spectrometry measurements. Other than one sample location, ICPMS results refuted conclusions formulated from historical alpha spectrometry measurements that anthropogenic uranium was present (Olson et al. 2003; Koeppen et al. 2004). Historical U-238:U-235 activity ratios suggested that uranium at these four locations was anthropogenic and slightly enriched in U-235. As can be seen in Table 3-65, results from analytical methods for U-234 and U-238 compared reasonably well; however, U-235 results did not. Figures 3-12, 3-13, and 3-14 show a graphical comparison between alpha spectrometric and mass spectrometric analyses for U-234, U-235, and U-238. On both Figures 3-12 and 3-14 (i.e., U-234 and U-238 comparison analyses), the slope of the best-fit linear regression is near 1, with a y-intercept near zero, showing that correlation between ICPMS and alpha spectrometry analyses is nearly 1:1, with very good agreement in results obtained using the two methods. However, the slope of the best-fit linear regression in Figure 3-13 (i.e., U-235 comparison analyses) is 1.8, indicating that U-235 measurements by alpha spectrometry are biased high compared to ICPMS results. Removing the upper, nonlinear point improves correlation between the two analytical methods, but increases the slope of the best-fit linear regression to 1.98. Thus, removing the upper, nonlinear point actually increases bias in the measurements.

Because U-238:U-235 activity ratios obtained by alpha spectrometry do not provide an accurate means for assessing the origin and enrichment of low-level uranium, alpha spectrometry results obtained in 1999 and 2000 were compared to isotope dilution thermal ionization mass spectrometry results obtained from an independent study (Roback et al. 2000). Compared RWMC soil-moisture samples were not part of the same sampling set, and sampling dates differ by 2 to 7 months. Nevertheless, notable bias is evident in U-238:U-235 ratios determined with alpha spectrometry measurements (i.e., high bias in low-level U-235 results) (see Figure 3-15). These data further support the November 2004 ICPMS data to confirm the bias associated with U-235 measurements by alpha spectrometric analyses. Activity ratios for U-234:U-238 from both analytical methods compare reasonably well, varying from 2 to 11%.

Table 3-65. Uranium concentrations measured by inductively coupled plasma-mass spectrometry and alpha spectrometry to assess isotopic ratios.

Lysimeter	Sample Date	Analytical Method	U-234 (pCi/L)	U-235 (pCi/L)	U-236 (pCi/L)	U-238 (pCi/L)	U-238:U-235 Ratio	U-234:U-238 Ratio
D06:DL01	11/15/04	ICPMS ^a	74	1.9	<0.026	42	22.4	1.75
D06:DL02	11/15/04	ICPMS ^a	95	1.7	<0.026	38	22.3	2.49
PA01:L15	11/15/04	ICPMS ^a	39	0.88	<0.026	18	20.1	2.19
TW1:DL04	11/15/04	ICPMS ^a	90	2.8	0.37	6.5	2.36	13.8
D06:DL01	11/15/04	ALS ^b	88 ± 7	2.8 ± 0.7	BDL	49 ± 4	18	1.8
D06:DL02	11/15/04	ALS ^b	100 ± 8	5.2 ± 1.0	BDL	39 ± 4	8	2.6
PA01:L15	11/15/04	ALS ^b	40 ± 4	0.9 ± 0.5	BDL	23 ± 3	26	1.7
TW1:DL04	11/15/04	ALS ^b	NS	NS	NS	NS	NA	NA
TW1:DL04	2/98 to 8/04 ^c	ALS ^b	91 ± 9	4.7 ± 0.9	BDL	9.1 ± 1.3	1.9	10.0
Natural uranium	—	—	—	—	—	—	21.7	~2.0 ^d

a. ICPMS (i.e., special low-level analysis methodology).

b. Alpha spectrometry (i.e., routine analysis method).

c. Because a sample was not available for routine analysis in November 2004, the 6-year mean concentration was included for comparison with ICPMS results.

d. U-234 and -238 in groundwater and soil moisture are not in secular equilibrium (i.e., the ratio is not 1:1).

ALS = alpha spectrometry

BDL = below detection limit

ICPMS = inductively coupled plasma-mass spectrometry

NS = no sample

Ratios are interpreted to be natural uranium; U-238:U-235 ratios by alpha spectrometry reflect low accuracy of measurement.

Ratios indicative of anthropogenic uranium with slight U-235 enrichment.

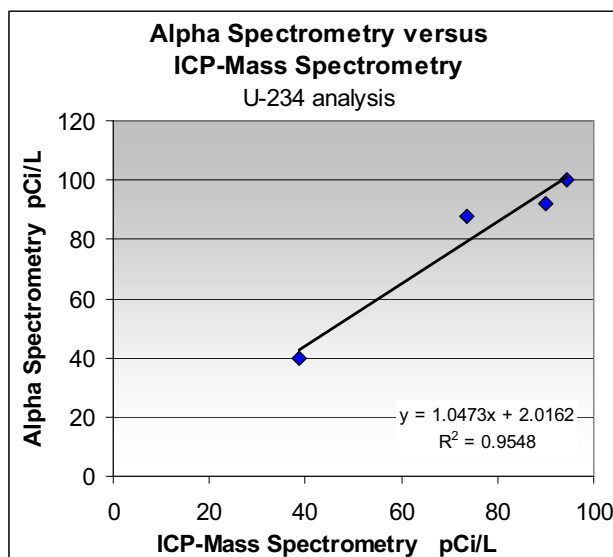


Figure 3-12. Reasonable agreement between alpha spectrometry and inductively coupled plasma-mass spectrometry analysis of uranium-234.

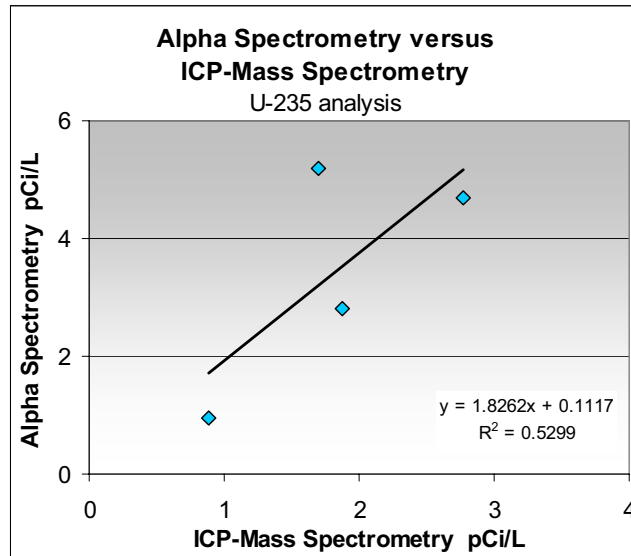


Figure 3-13. Poor agreement between alpha spectrometry and inductively coupled plasma-mass spectrometry analysis of uranium-235.

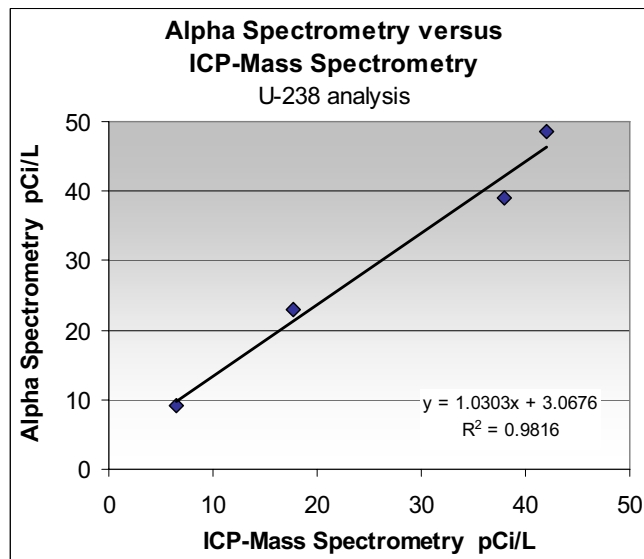


Figure 3-14. Reasonable agreement between alpha spectrometry and inductively coupled plasma-mass spectrometry analysis of uranium-238.

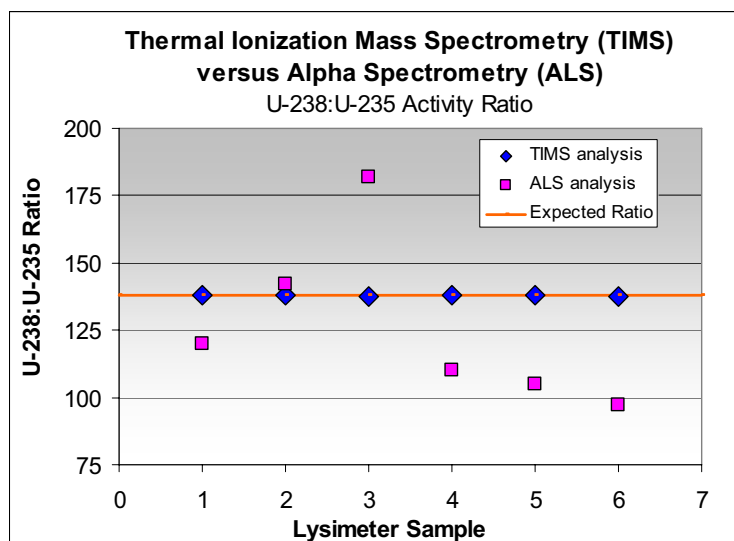


Figure 3-15. Comparison of U-238:U-235 activity ratios measured by isotope dilution thermal ionization mass spectrometry and alpha spectrometry in 1999 and 2000.

Because of the very large uncertainty and bias associated with low-level U-235 measurements by alpha spectroscopy, U-238:U-235 ratios were evaluated on aquifer background samples to determine whether the ratio pattern is similar to that observed in soil-moisture samples. The U-238:U-235 ratios show a similar pattern to that of the soil-moisture samples, indicating the historical conclusion—that anthropogenic uranium with a slight U-235 enrichment was present—was erroneous (see Figure 3-16). In the Roback et al. (2000) study, using thermal ionization mass spectrometry, soil-moisture samples with uranium concentrations significantly greater than background levels (up to 144 ppb) and aquifer samples were found to have natural U-238:U-235 isotope ratios, and no U-236 anthropogenic component was detected. Most of these samples were interpreted as natural uranium. Therefore, U-238:U-235 ratios, which were solely used to determine the origin of uranium with concentrations above upper background levels, are no longer regarded as appropriate for uranium assessment without also applying U-234:U-238 activity ratios. Nearly all aquifer samples show similarly enriched uranium values, corroborating the bias in U-235 measurements obtained with alpha spectrometry.

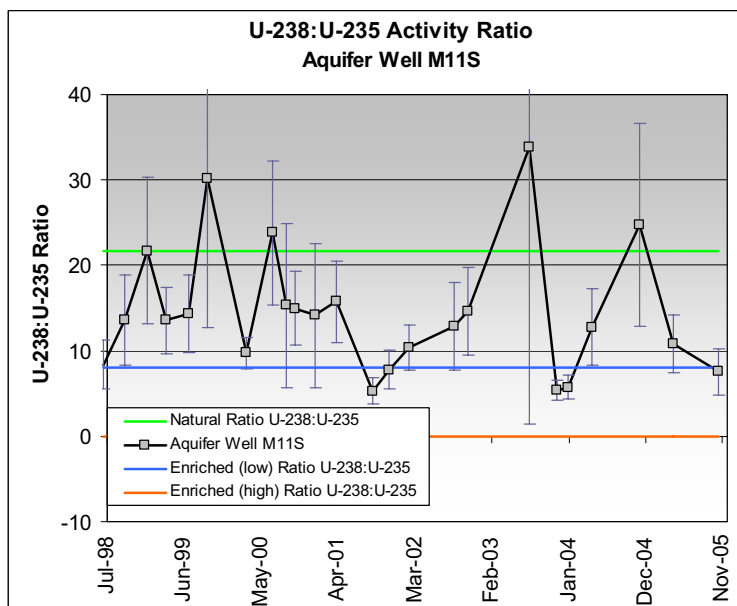


Figure 3-16. Aquifer background activity ratios for U-238:U-235 in Well M11S.

Using current information, all vadose zone lysimeter samples with detected concentrations of U-234, U-235, and U-238 above upper background levels were reassessed using both U-234:U-238 and U-238:U-235 activity ratios. As demonstrated in discussions of uranium monitoring data (see Sections 3.12.3, 3.12.4, and 3.12.5), the correlation between those two activity ratios (i.e., U-234:U-238 and U-238:U-235) shows that all locations in the vadose zone and aquifer with uranium concentrations above upper background levels or tolerance limits are characteristic of natural uranium, except Lysimeter TW1:DL04 beneath Pit 5 at a depth of 31 m (102 ft).

3.12.1.2 Background Concentration Ranges for Evaluating Uranium. Methodology for determining upper background concentration limits for uranium in vadose zone soil-moisture samples was recently reviewed and modified. The historical conservative upper-limit value (i.e., mean concentration, plus one standard deviation of the mean) was replaced, beginning in FY 2005, with the maximum concentration of each uranium isotope observed in the background data set. This change was warranted because adequate background data sets have now been accrued to provide a better representation of uranium background concentrations in local soil moisture (pore water). Areas in the SDA with possible uranium abnormalities and areas characteristic of background were both observed and evaluated. Background soil-moisture samples are routinely collected from 13 lysimeters located in eight wells outside the SDA boundaries (see Figure 3-17). Table 3-66 provides the soil-moisture background data accrued since 1998. Note that maximum concentration values used for comparison are similar to the mean plus three times the standard deviation of the mean. Constraints on using or selecting a maximum concentration value require that the value (1) be an expected value, (2) be characteristic of variances typically observed, and (3) not be a statistical outlier. Local background levels for the vadose zone were established using data from lysimeters installed in the B-C and C-D interbeds located outside the SDA boundaries. Values for interbed sediment may not be representative of alluvium at shallower depths, but were used for comparison only to interpret data from the A-B interbed (sediment from the surface to the first basalt interface). Many geochemical properties in the alluvial sediments inside the SDA have been affected by buried chemical waste, application of magnesium chloride brine, and production of significant quantities of carbon dioxide by biodegradation of waste products (causing uranium to form complexes with carbonates). These mechanisms, principally uranium carbonate complexes, will cause natural uranium levels at affected locations to be significantly elevated. Therefore, comparing these elevated natural uranium concentrations to background levels obtained at pristine locations outside the SDA may cause misinterpretation or misunderstanding, leading to a wrong assumption. Therefore, absolute concentrations of uranium background may not be appropriate for assessing uranium, and application of U-234:U-238 and U-238:U-235 ratios may provide all the necessary data. Decision criteria for better assessing uranium will be investigated and developed in FY 2006.

The upper background tolerance limits for assessing uranium in aquifer samples remain unchanged: 1.92 pCi/L and 0.90 pCi/L for U-234 and U-238, respectively (Leecaster, Koeppen, Olson 2003). An upper tolerance limit for U-235 could not be statistically established because most U-235 data are nondetections and yield large statistical variances. Therefore, the maximum concentration of U-235, obtained from aquifer background data accrued since 1998, is used as the upper concentration limit and is determined the same way as soil-moisture backgrounds. Table 3-67 shows the uranium background data used to establish the U-235 upper limit value for the aquifer.

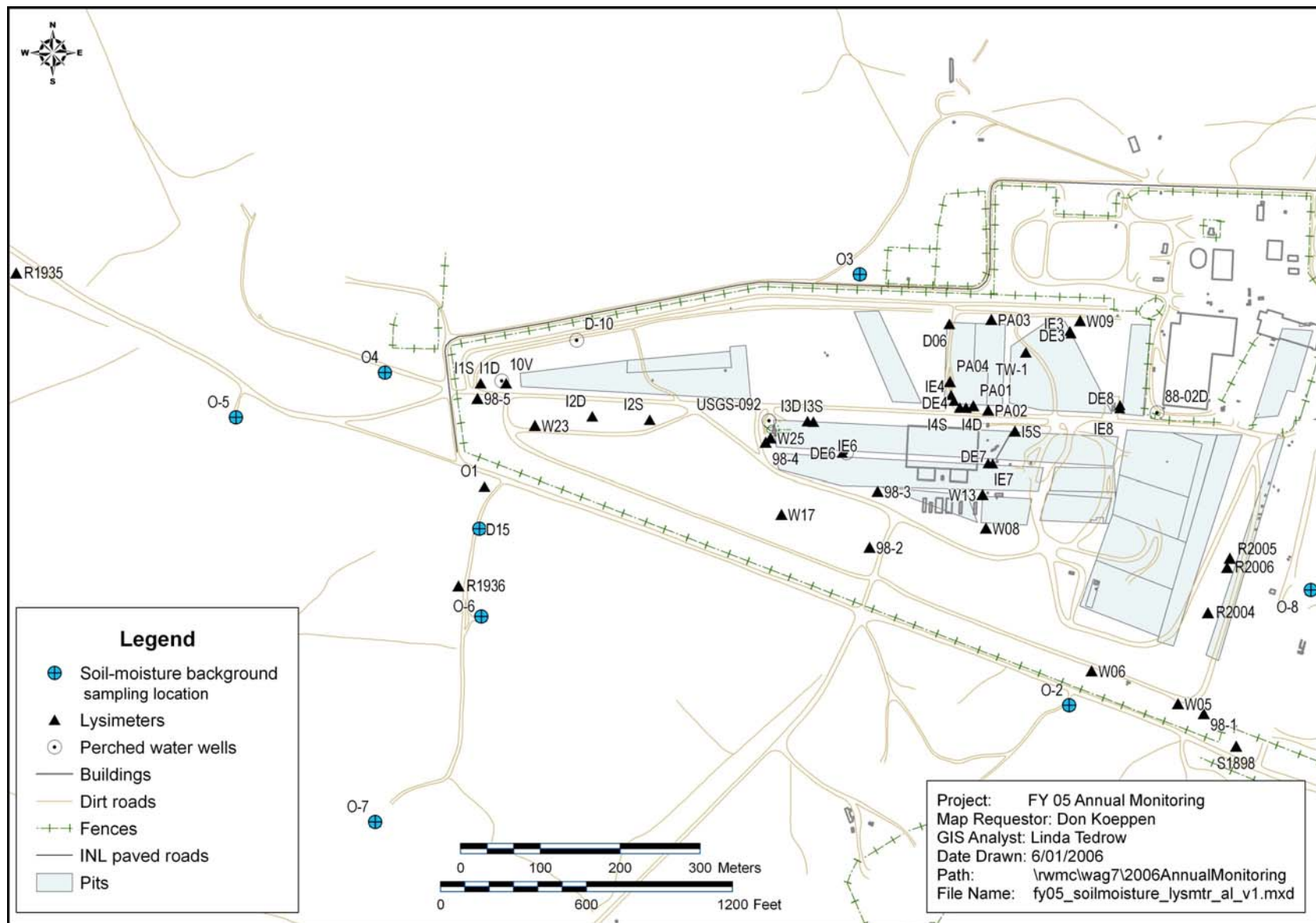


Figure 3-17. Location where soil-moisture background samples were obtained.

Table 3-66. Uranium background concentrations and upper limit values for assessing soil-moisture samples.

Date Sampled	Lysimeter Well ID	U-234 (pCi/L)	1 σ (pCi/L)	Flag	U-235 (pCi/L)	1 σ (pCi/L)	Flag	U-238 (pCi/L)	1 σ (pCi/L)	Flag	Total Uranium (μ g/L)	1 σ (μ g/L)	U-234:U-238 Ratio	U-238:U-235 Ratio
06/20/00	O2S (106 ft)	2.84	0.42	J	0.60	0.21	J	2.84	0.41	—	8.7	1.2	1.00	—
06/20/00		3.31	0.81	UJ	0.85	0.40	UJ	3.06	0.76	—	9.5	2.3	1.08	—
05/01/03		4.99	0.68	—	0.33	0.17	U	2.68	0.46	—	8.1	1.4	1.86	—
07/10/03		2.55	0.72	—	0.36	0.32	U	0.31	0.25	U	—	—	—	—
01/27/04		4.97	0.98	—	0.20	0.23	U	1.66	0.54	—	5.0	1.6	2.99	—
05/05/04		3.81	0.91	—	0.14	0.19	U	3.21	0.84	—	9.6	2.5	1.19	—
11/17/04		4.19	0.82	—	0.44	0.25	U	3.37	0.73	—	10.2	2.2	1.24	—
05/26/05		8.52	1.24	—	0.42	0.24	U	3.86	0.78	—	11.7	2.3	2.21	—
07/17/02	O3S (87 ft)	1.07	0.40	J	0.32	0.23	U	0.37	0.22	U	1.3	0.7	—	—
10/21/02		0.28	0.26	U	0.29	0.17	U	0.29	0.17	U	1.0	0.5	—	—
01/08/03		0.13	0.05	UJ	-0.05	0.03	U	0.02	0.03	U	0.0	0.1	—	—
05/01/03		0.68	0.29	UJ	0.77	0.28	UJ	0.33	0.17	—	1.3	0.6	—	—
07/23/03		2.01	0.72	J	0.69	0.43	U	1.22	0.58	UJ	3.9	1.7	—	—
01/27/04		0.45	0.31	U	-0.03	0.15	U	0.27	0.19	U	0.8	0.6	—	—
05/06/04		0.43	0.30	U	0.17	0.17	U	-0.08	0.06	U	—	—	—	—
11/16/04		0.57	0.33	U	0.45	0.29	U	-0.08	0.06	U	—	—	—	—
02/08/05		1.34	0.50	J	0.00	1.00	U	0.61	0.31	—	1.8	0.9	—	—
05/26/05		0.51	0.29	U	0.01	0.16	U	0.15	0.22	U	0.4	0.6	—	—
08/10/05		0.30	0.26	U	0.14	0.19	U	0.26	0.21	U	0.8	0.6	—	—
12/04/00	O4S (108.5 ft)	1.78	0.40	—	-0.05	0.11	U	0.87	0.26	—	2.6	0.8	2.04	—
07/17/02		3.13	0.62	—	0.56	0.26	UJ	1.12	0.34	—	3.6	1.0	2.79	—
01/08/03		1.11	0.22	—	0.00	0.05	U	0.39	0.12	—	1.1	0.4	2.88	—
05/01/03		2.74	0.37	—	0.49	0.16	J	1.04	0.23	—	3.3	0.7	2.63	2.1
07/10/03		3.15	0.75	—	0.15	0.15	U	1.11	0.43	J	3.4	1.3	—	—
10/29/03		2.36	0.70	—	-0.12	0.07	U	1.33	0.50	J	3.9	1.5	—	—
01/27/04		2.64	0.81	—	-0.10	0.07	U	0.43	0.31	U	1.2	0.9	—	—

Table 3-66. (continued).

Date Sampled	Lysimeter Well ID	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratio	U-238:U-235 Ratio
06/20/00	O5S (104 ft)	4.87	0.55	—	0.65	0.18		1.55	0.28	UJ	4.9	0.9	3.14	2.4
06/20/00		3.45	0.73	—	0.80	0.37	UJ	1.31	0.47	J	4.3	1.4	—	—
07/17/02		4.20	0.68	—	-0.17	0.09	U	2.00	0.46	—	5.9	1.4	2.10	—
10/21/02		2.92	0.59	—	0.23	0.17	U	1.37	0.40	—	4.2	1.2	2.13	—
01/08/03		1.37	0.23	—	-0.03	0.04	U	0.56	0.15	—	1.7	0.4	2.44	—
05/01/03		1.53	0.46	—	0.23	0.15	U	1.66	0.34	—	5.0	1.0	0.92	—
07/23/03		2.39	0.63	—	0.37	0.26	U	1.41	0.47	J	4.4	1.4	—	—
10/29/03		1.83	0.56	—	0.07	0.15	U	0.97	0.39	J	2.9	1.2	—	—
01/27/04		2.14	0.55	—	-0.03	0.03	U	0.83	0.35	J	2.5	1.0	—	—
05/06/04		0.81	0.41	U	0.28	0.23	U	1.37	0.50	J	4.2	1.5	—	—
05/26/05		1.02	0.37	J	0.35	0.22	U	0.32	0.23	U	1.1	0.7	—	—
08/10/05		2.43	0.63	—	0.50	0.32	U	1.11	0.43	J	3.5	1.3	—	—
01/08/03	O5S (119 ft)	1.23	0.21	—	0.06	0.04	U	0.44	0.12	—	1.3	0.3	2.81	—
05/01/03		4.09	0.61	—	0.95	0.29	—	1.08	0.29	—	3.7	1.0	3.79	1.1
07/10/03		3.70	0.88	—	1.25	0.50	J	2.49	0.70	—	8.0	2.2	1.49	—
10/29/03		0.63	0.34	U	0.52	0.30	U	1.59	0.51	—	5.0	1.5	—	—
05/06/04		0.94	0.47	U	1.17	0.51	U	0.66	0.43	U	2.5	1.4	—	—
11/16/04		6.96	1.36	—	0.40	0.33	U	1.72	0.66	J	5.3	2.0	—	—
05/26/05		7.21	1.07	—	0.19	0.19	U	3.01	0.67	—	9.0	2.0	2.40	—
04/20/98	D15:DL06 (97.9 ft)	2.04	0.65	—	0.03	0.14	U	1.07	0.40	—	3.2	1.2	—	—
08/03/98		2.42	0.50	—	0.64	0.27	UJ	1.19	0.34	—	3.8	1.1	2.03	—
12/01/98		1.71	0.33	—	0.59	0.20	—	0.68	0.22	—	2.3	0.7	2.53	—
06/19/00		4.14	0.55	UJ	1.02	0.27	—	0.73	0.26	UJ	2.6	0.9	—	—
06/19/00		2.50	0.60	—	0.80	0.35	UJ	1.58	0.48	—	5.1	1.5	1.58	—
09/11/00		1.33	0.53	UJ	-0.04	0.04	U	1.49	0.53	U	4.4	1.6	—	—
05/15/01		3.75	1.24	—	-0.08	0.08	U	0.60	0.49	U	1.7	1.5	—	—
07/17/02		5.97	1.80	—	-0.18	0.75	U	2.05	1.04	U	6.0	3.1	—	—

Table 3-66. (continued).

Date Sampled	Lysimeter Well ID	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratio	U-238:U-235 Ratio
10/21/02		2.14	0.51	—	0.24	0.21	U	1.12	0.37	—	3.4	1.1	—	—
05/01/03		2.70	0.44	—	0.33	0.15	UJ	0.68	0.23	—	2.2	0.7	—	—
07/23/03		1.54	0.50	—	0.62	0.31	U	0.54	0.32	U	1.9	1.0	—	—
10/29/03		3.04	0.81	—	-0.08	0.20	U	0.31	0.31	U	0.9	0.9	—	—
05/05/04		1.27	0.48	UJ	-0.30	0.10	U	0.01	0.16	U	-0.1	0.5	—	—
11/16/04		1.69	0.63	J	0.21	0.31	U	1.39	0.60	UJ	4.2	1.8	—	—
02/07/05		0.30	0.50	U	-0.03	0.17	U	0.36	0.29	U	1.1	0.9	—	—
05/26/05		2.44	0.62	—	-0.10	0.06	U	0.35	0.25	U	1.0	0.7	—	—
08/10/05		1.86	0.55	—	0.17	0.17	U	1.44	0.47	—	4.4	1.4	1.29	—
10/21/02	D15:DL07 (32.2 ft)	4.05	1.07	—	0.55	0.40	U	1.84	0.68	J	5.7	2.0	—	—
10/21/02	O2D (240 ft)	4.69	0.78	—	0.05	0.11	U	3.04	0.61	—	9.1	1.8	1.54	—
01/08/03		2.43	0.34	—	0.02	0.07	U	1.60	0.26	—	4.8	0.8	1.52	—
10/29/03		4.80	1.10	—	0.11	0.21	U	1.17	0.55	UJ	3.5	1.6	—	—
08/30/04		2.33	0.62	—	0.26	0.22	U	1.34	0.46	J	4.1	1.4	—	—
10/29/03	O3D (219 ft)	0.97	0.52	U	-0.26	0.28	U	-0.11	0.08	U	-0.4	0.3	—	—
08/30/04		0.98	0.49	UJ	0.21	0.21	U	0.29	0.28	U	1.0	0.8	—	—
12/05/00	O4D (225 ft)	1.02	0.57	U	-0.29	0.24	U	0.59	0.38	U	1.6	1.1	—	—
10/21/02		2.51	0.58	—	0.47	0.24	U	0.94	0.39	UJ	3.0	1.2	—	—
10/21/02		1.93	0.60	—	0.70	0.42	U	-0.09	0.32	U	0.1	1.0	—	—
01/08/03		-0.04	0.04	U	0.02	0.04	U	-0.02	0.03	U	-0.1	0.1	—	—
05/01/03		0.35	0.17	U	0.27	0.14	U	0.32	0.13	J	1.1	0.4	—	—
07/23/03		0.80	0.38	UJ	-0.15	0.07	U	0.08	0.16	U	0.2	0.5	—	—
10/29/03		-0.10	0.26	U	0.16	0.16	U	0.41	0.29	U	1.3	0.9	—	—
01/27/04		0.51	0.32	U	0.01	0.14	U	0.47	0.26	U	1.4	0.8	—	—
05/06/04		0.74	0.41	U	0.61	0.33	U	0.12	0.17	U	0.6	0.6	—	—
08/30/04		1.21	0.45	—	0.27	0.22	U	0.44	0.25	U	1.4	0.8	—	—

Table 3-66. (continued).

Date Sampled	Lysimeter Well ID	U-234 (pCi/L)	1 σ (pCi/L)	Flag	U-235 (pCi/L)	1 σ (pCi/L)	Flag	U-238 (pCi/L)	1 σ (pCi/L)	Flag	Total Uranium (μ g/L)	1 σ (μ g/L)	U-234:U-238 Ratio	U-238:U-235 Ratio
11/16/04		1.41	0.56	J	0.44	0.31	U	0.79	0.48	U	2.6	1.4	—	—
02/08/05		0.19	0.22	U	-0.07	0.05	U	0.22	0.21	U	0.6	0.6	—	—
08/08/05		1.92	0.60	UJ	0.95	0.43	J	0.93	0.42	UJ	3.2	1.3	—	—
06/20/00	O6D (225 ft)	3.62	0.65	J	1.34	0.47	J	1.14	0.40	UJ	4.0	1.3	—	—
09/11/00		0.71	0.30	UJ	0.14	0.17	U	0.53	0.22	J	1.6	0.7	—	—
07/17/02		1.52	0.50	—	0.55	0.25	UJ	0.39	0.24	U	1.4	0.8	—	—
07/17/02	O7D (240 ft)	0.65	0.27	UJ	0.53	0.24	UJ	0.24	0.20	U	1.0	0.6	—	—
10/21/02		1.10	0.38	J	0.27	0.16	U	0.26	0.24	U	0.9	0.7	—	—
05/01/03		0.48	-0.07	UJ	-0.07	0.05	U	0.45	0.17	J	1.3	0.5	—	—
07/23/03		1.99	0.60	—	0.00	1.00	U	1.49	0.50	J	4.4	1.5	—	—
10/29/03		6.17	1.21	—	0.24	0.28	U	2.47	0.75	—	7.5	2.2	2.50	—
01/27/04		1.71	0.67	UJ	0.10	0.34	U	2.02	0.70	J	6.1	2.1	—	—
05/06/04		0.47	0.32	U	0.23	0.22	U	0.39	0.27	U	1.3	0.8	—	—
08/30/04		5.12	0.93	—	0.12	0.23	U	2.77	0.69	—	8.3	2.0	1.85	—
05/26/05		3.00	0.92	—	0.95	0.54	U	2.95	0.92	—	9.2	2.8	1.02	—
04/25/02	O8D (228 ft)	0.77	0.32	UJ	-0.04	0.04	U	0.44	0.24	U	1.3	0.7	—	—
Mean:		2.26	0.57		0.29	0.24		1.07	0.38		3.4	1.2	2.05	1.89
Standard deviation:		1.74			0.35			0.91			2.7		0.73	0.67
Minimum:		-0.10			-0.30			-0.11			-0.4		Application of U-238:U-235 ratio not appropriate because of high U-235 measurement uncertainties	
Maximum:		8.52			1.34			3.86			11.7			
Mean + 3 standard deviations:		7.49			1.34			3.81			11.6			

Note: Results shown in **bold font** are positive detections (i.e., $>3\sigma$ and $>$ minimum detectable concentration).

— = Isotopic uranium ratio not calculated because one or both of the isotopic results were not positive detections.

Values are background upper limit values used to evaluate uranium in soil-moisture samples.

Table 3-67. Uranium background concentrations and upper limit values for assessing aquifer samples.

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
05/12/98	M1S	0.78	0.07	—	0.024	0.008	UJ	0.35	0.04	—	1.06	0.12	2.2	—
07/07/98		1.00	0.11	—	0.091	0.030	—	0.53	0.07	—	1.62	0.22	1.9	5.8
07/07/98		0.88	0.10	—	0.082	0.024	—	0.51	0.07	—	1.55	0.20	1.7	6.2
10/08/98		0.91	0.10	J	0.017	0.010	UJ	0.35	0.05	J	1.06	0.15	2.6	—
10/08/98		0.83	0.09	J	0.017	0.012	UJ	0.34	0.05	J	1.02	0.14	2.4	—
01/12/99		0.90	0.08	J	0.016	0.008	UJ	0.36	0.04	—	1.07	0.12	2.5	—
01/12/99		0.85	0.08	J	0.015	0.009	U	0.38	0.04	—	1.13	0.13	2.3	—
04/06/99		0.89	0.08	—	0.030	0.010	J	0.38	0.04	—	1.14	0.12	2.4	—
04/06/99		0.93	0.08	—	0.050	0.013	—	0.43	0.05	—	1.30	0.14	2.2	8.6
07/13/99		0.71	0.09	—	0.006	0.009	U	0.25	0.04	—	0.75	0.13	2.8	—
07/13/99		0.87	0.10	—	0.017	0.012	U	0.34	0.06	—	1.03	0.16	2.5	—
10/06/99		0.84	0.08	—	0.016	0.007	J	0.34	0.04	—	1.03	0.12	2.5	—
10/06/99		0.87	0.08	—	0.023	0.008	Jdk ^b	0.40	0.04	—	1.20	0.13	2.2	—
03/21/00		0.89	0.07	—	0.029	0.008	UJ	0.41	0.04	—	1.22	0.11	2.2	—
03/21/00		0.83	0.07	—	0.043	0.009	UJ	0.46	0.04	—	1.39	0.12	1.8	—
07/11/00		0.72	0.07	—	0.016	0.006	J	0.39	0.04	—	1.15	0.12	1.9	—
07/11/00		0.83	0.08	—	0.012	0.009	U	0.38	0.04	—	1.14	0.13	2.2	—
09/14/00		0.88	0.13	—	0.022	0.017	U	0.41	0.07	—	1.24	0.22	2.1	—
09/14/00		0.89	0.13	—	0.042	0.031	U	0.43	0.08	—	1.30	0.25	2.1	—
10/24/00		1.14	0.10	—	0.037	0.010	—	0.53	0.05	—	1.60	0.16	2.1	14.4
10/24/00		0.79	0.07	—	0.016	0.007	Jdk ^b	0.42	0.04	—	1.24	0.13	1.9	—
01/16/01		0.89	0.11	—	-0.002 ^a	0.009 ^a	U	0.41	0.07	—	1.23	0.20	2.2	—
01/16/01		0.84	0.11	—	0.031	0.018	U	0.41	0.07	—	1.23	0.21	2.0	—
04/16/01		0.85	0.08	—	0.019	0.008	J	0.41	0.04	—	1.23	0.13	2.1	—
09/25/01		0.78	0.08	—	0.037	0.012	J	0.38	0.05	—	1.13	0.14	2.1	—

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
12/05/01		0.89	0.09	—	0.032	0.013	J	0.42	0.05	—	1.27	0.15	2.1	—
02/19/02		0.91	0.09	—	0.023	0.010	UJ	0.36	0.04	—	1.08	0.13	2.5	—
05/15/02		0.82	0.07	—	0.026	0.010	J	0.40	0.04	—	1.21	0.13	2.0	—
09/12/02		0.86	0.09	—	0.004	0.009	U	0.42	0.05	—	1.25	0.15	2.0	—
11/05/02		0.83	0.09	—	0.023	0.019	U	0.43	0.06	—	1.28	0.17	1.9	—
02/05/03		0.80	0.07	—	0.092	0.017	—	0.38	0.04	—	1.18	0.12	2.1	4.2
02/05/03		0.86	0.08	—	0.024	0.012	UJ	0.42	0.04	—	1.26	0.13	2.1	—
05/06/03		0.92	0.08	—	0.043	0.011	—	0.39	0.04	—	1.18	0.12	2.3	9.2
08/06/03		0.90	0.10	—	0.042	0.016	J	0.38	0.06	—	1.16	0.17	2.3	—
12/02/03		0.77	0.08	—	0.022	0.010	—	0.34	0.04	—	1.03	0.12	2.2	—
01/27/04		0.86	0.09	—	0.044	0.017	—	0.38	0.05	—	1.15	0.15	2.3	—
04/27/04		0.92	0.09	—	0.098	0.022	—	0.35	0.05	—	1.08	0.14	2.6	3.6
12/01/04		0.81	0.08	—	0.039	0.015	J	0.38	0.05	—	1.14	0.14	2.2	—
04/28/05		0.94	0.08	—	0.044	0.016	J	0.46	0.05	—	1.37	0.14	2.1	—
05/12/98	M3S	1.44	0.12	—	0.025	0.009	UJ	0.60	0.06	—	1.80	0.17	2.4	—
07/07/98		1.65	0.16	—	0.086	0.031	Jdk ^b	0.64	0.08	—	1.95	0.24	2.6	—
10/07/98		1.48	0.14	J	0.038	0.014	J	0.66	0.07	J	1.98	0.21	2.2	—
01/12/99		1.36	0.12	J	0.058	0.016	—	0.73	0.07	—	2.19	0.22	1.9	12.5
04/06/99		1.37	0.11	—	0.030	0.010	J	0.62	0.06	—	1.85	0.17	2.2	—
07/23/99		1.40	0.12	—	0.039	0.011	—	0.65	0.06	—	1.96	0.18	2.1	16.6
10/06/99		1.27	0.11	—	0.040	0.011	—	0.65	0.06	—	1.95	0.19	2.0	16.2
03/21/00		1.48	0.11	U	0.078	0.013	U	0.68	0.06	—	2.05	0.16	2.2	—
07/11/00		1.32	0.11	—	0.041	0.011	—	0.64	0.06	—	1.91	0.19	2.1	15.6
09/14/00		1.44	0.18	—	0.026	0.016	U	0.72	0.11	—	2.15	0.31	2.0	—
10/24/00		1.32	0.11	—	0.051	0.013	—	0.60	0.06	—	1.81	0.18	2.2	11.9
01/16/01		1.61	0.19	—	0.003	0.011	U	0.77	0.11	—	2.28	0.32	2.1	—

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
04/16/01	3-133	1.37	0.11	—	0.038	0.010	—	0.65	0.06	—	1.95	0.18	2.1	17.2
04/16/01		1.36	0.12	—	0.036	0.011	—	0.64	0.06	—	1.91	0.18	2.1	18.0
09/25/01		1.50	0.15	—	0.296 ^a	0.049 ^a	—	0.46	0.07	—	1.52	0.19	3.2	—
12/05/01		1.38	0.12	—	0.144	0.027	—	0.59	0.06	—	1.81	0.19	2.4	4.1
02/19/02		1.46	0.11	—	0.034	0.009	—	0.59	0.05	—	1.76	0.16	2.5	17.4
05/15/02		1.35	0.11	—	0.026	0.010	J	0.57	0.58	—	1.72	1.74	2.4	—
09/12/02		1.34	0.11	—	0.073	0.016	—	0.57	0.06	—	1.72	0.17	2.4	7.7
11/05/02		1.31	0.12	—	0.066	0.02	—	0.58	0.06	—	1.74	0.18	2.3	8.7
02/05/03		1.40	0.11	—	0.048	0.01	—	0.66	0.06	—	1.97	0.17	2.1	13.7
05/12/03		1.44	0.12	—	0.109	0.019	—	0.62	0.06	—	1.88	0.17	2.3	5.7
08/06/03		1.54	0.15	—	0.064	0.021	—	0.64	0.08	—	1.93	0.23	2.4	9.9
12/02/03		1.54	0.11	—	0.061	0.013	—	0.63	0.05	—	1.91	0.16	2.4	10.3
01/27/04		1.48	0.14	—	0.058	0.019	—	0.63	0.07	—	1.91	0.22	2.3	10.8
04/27/04		1.49	0.14	—	0.133	0.027	—	0.53	0.06	—	1.64	0.19	2.8	4.0
12/01/04		1.43	0.11	—	0.024	0.010	J	0.57	0.06	—	1.72	0.17	2.5	—
04/28/05		1.37	0.11	—	0.080	0.021	—	0.54	0.06	—	1.64	0.17	2.5	6.7
05/11/98	M4D	0.49	0.05	—	0.022	0.010	UJ	0.22	0.03	—	0.66	0.09	2.2	—
05/11/98		0.45	0.04	—	0.046	0.011	UJ	0.25	0.03	—	0.76	0.09	1.8	—
07/06/98		0.61	0.07	—	0.044	0.014		0.33	0.04	—	1.00	0.13	1.9	7.4
10/07/98		0.53	0.07	J	0.010	0.010	UJ	0.29	0.04	J	0.86	0.13	1.9	—
01/12/99		0.44	0.05	J	0.018	0.008	UJ	0.23	0.03	—	0.69	0.09	1.9	—
04/06/99		0.42	0.05	—	0.003	0.007	U	0.21	0.03	—	0.63	0.09	2.0	—
07/14/99		0.42	0.06	—	0.003	0.007	U	0.28	0.05	—	0.83	0.14	1.5	—
10/07/99		1.49 ^a	0.13 ^a	—	0.016	0.008	U	0.67 ^a	0.06 ^a	—	2.00	0.18	—	—
03/21/00		0.40	0.04	—	0.019	0.005	UJ	0.22	0.02	—	0.66	0.07	1.8	—
09/13/00		0.42	0.08	—	0.012	0.015	U	0.23	0.05	—	0.70	0.16	1.8	—

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
10/18/00		0.52	0.05	—	0.010	0.005	J	0.25	0.03	—	0.76	0.09	2.0	25.2
01/15/01		0.41	0.07	U	0.017	0.013	U	0.25	0.05	—	0.76	0.14	1.6	—
04/18/01		0.56	0.06	—	0.015	0.009	U	0.30	0.04	—	0.91	0.11	1.8	—
09/18/01		0.55	0.07	—	0.001	0.023	U	0.32	0.05	—	0.94	0.15	1.7	—
12/11/01		0.45	0.05	—	0.022	0.012	U	0.28	0.03	—	0.83	0.10	1.6	—
02/19/02		0.47	0.05	—	0.013	0.009	U	0.28	0.03	—	0.84	0.10	1.7	—
05/14/02		1.68 ^a	0.14 ^a	—	0.046	0.015	—	0.78 ^a	0.07 ^a	—	—	—	—	—
09/11/02		0.45	0.04	—	0.022	0.009	—	0.23	0.03	—	0.69	0.08	2.0	—
11/12/02		0.46	0.05	—	0.020	0.008	UJ	0.20	0.03	—	0.60	0.08	2.3	—
02/03/03		0.41	0.04	—	0.031	0.010	—	0.27	0.03	—	0.82	0.10	1.5	8.7
05/05/03		0.43	0.04	—	0.042	0.011	—	0.22	0.03	—	0.66	0.08	2.0	5.2
08/05/03		0.40	0.05	—	0.010	0.009	U	0.28	0.04	—	0.85	0.13	1.4	—
12/02/03		0.40	0.04	—	0.022	0.010	UJ	0.20	0.03	—	0.61	0.08	2.0	—
01/21/04		0.38	0.04	—	0.014	0.01	U	0.20	0.03	—	0.61	0.09	1.9	—
04/29/04		0.48	0.06	—	0.031	0.012	—	0.17	0.03	—	0.50	0.09	2.9	—
11/23/04		0.42	0.03	—	0.033	0.009	—	0.20	0.02	—	0.60	0.07	2.1	6.0
05/03/05		0.51	0.05	—	0.023	0.011	UJ	0.24	0.03	—	0.72	0.10	2.1	—
05/12/98	M6S	1.12	0.09	—	0.026	0.009	UJ	0.54	0.05	—	1.63	0.15	2.1	—
07/06/98		1.30	0.13	—	0.088	0.028		0.65	0.08	—	1.97	0.25	2.0	7.3
10/07/98		1.23	0.12	J	0.017	0.008	UJ	0.57	0.06	J	1.70	0.19	2.2	—
01/13/99		1.23	0.11	J	0.024	0.010	J	0.60	0.06	—	1.78	0.18	2.1	24.9
04/06/99		1.22	0.10	—	0.023	0.012	U	0.58	0.06	—	1.73	0.17	2.1	—
07/14/99		1.21	0.11	—	0.019	0.009	UJ	0.53	0.06	—	1.58	0.17	2.3	—
10/07/99		1.23	0.10	—	0.031	0.010	—	0.58	0.06	—	1.75	0.17	2.1	18.9
03/20/00		1.20	0.09	—	0.047	0.009	J	0.56	0.05	—	1.70	0.14	2.1	12.1
07/12/00		1.00	0.09	—	0.037	0.010	—	0.48	0.05	—	1.44	0.14	2.1	13.0

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
09/19/00		1.31	0.17	—	0.034	0.017	U	0.52	0.08	—	1.55	0.25	2.5	—
10/18/00		1.05	0.09	—	0.023	0.012	U	0.45	0.05	—	1.35	0.15	2.3	—
01/15/01		1.12	0.13	—	0.026	0.015	U	0.45	0.07	—	1.34	0.20	2.5	—
04/23/01		1.12	0.09	—	0.047	0.011	—	0.58	0.05	—	1.74	0.16	1.9	12.2
09/18/01		1.05	0.10	—	0.199 ^a	0.036 ^a	—	0.57	0.07	—	1.78	0.20	1.9	—
11/28/01		1.08	0.11	—	0.050	0.016	—	0.56	0.07	—	1.69	0.20	1.9	11.3
11/28/01		1.31	0.12	—	0.025	0.013	U	0.62	0.07	—	1.86	0.21	2.1	—
02/25/02		1.17	0.10	—	0.063	0.014	—	0.54	0.05	—	1.65	0.16	2.2	8.6
05/14/02		1.05	0.10	—	0.066	0.020	—	0.44	0.05	—	1.34	0.15	2.4	6.6
09/11/02		1.25	0.10	—	0.046	0.011	—	0.54	0.05	—	1.62	0.15	2.3	11.7
11/11/02		1.15	0.10	—	0.023	0.011	UJ	0.62	0.06	—	1.85	0.18	1.9	—
02/03/03		1.23	0.10	—	0.044	0.010	—	0.54	0.05	—	1.64	0.15	2.3	12.4
04/28/03		1.09	0.09	—	0.071	0.023	—	0.56	0.05	—	1.69	0.16	2.0	7.9
08/04/03		1.34	0.13	—	0.065	0.020	—	0.61	0.07	—	1.85	0.21	2.2	9.5
12/01/03		1.24	0.11	—	0.058	0.015	—	0.60	0.06	—	1.80	0.18	2.1	10.2
01/20/04		1.06	0.10	—	0.046	0.016	J	0.46	0.06	—	1.40	0.17	2.3	—
05/03/04		1.18	0.10	—	0.062	0.016	—	0.56	0.06	—	1.69	0.17	2.1	9.1
11/23/04		1.32	0.07	—	0.031	0.009	—	0.65	0.04	—	1.94	0.13	2.0	21.0
04/27/05		1.50	0.12	—	0.048	0.017	J	0.70	0.07	—	2.09	0.20	2.2	—
05/12/98	M7S	1.36	0.11	—	0.029	0.012	UJ	0.56	0.05	—	1.66	0.16	2.5	—
07/07/98		1.54	0.14	—	0.086	0.021	—	0.74	0.08	—	2.25	0.23	2.1	8.7
10/07/98		1.39	0.13	J	0.036	0.015	UJ	0.58	0.07	J	1.74	0.20	2.4	—
01/13/99		1.32	0.11	J	0.029	0.012	UJ	0.51	0.05	—	1.54	0.16	2.6	—
04/06/99		1.33	0.11	—	0.038	0.012	—	0.67	0.06	—	2.00	0.19	2.0	17.6
07/12/99		1.09	0.12	—	0.041	0.017	J	0.52	0.07	—	1.57	0.21	2.1	—
10/06/99		1.31	0.11	—	0.050	0.013	—	0.69	0.07	—	2.08	0.20	1.9	13.8

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
03/21/00		1.28	0.09	—	0.037	0.008	UJ	0.58	0.05	—	1.75	0.14	2.2	—
07/11/00		1.40	0.12	—	0.020	0.010	U	0.60	0.06	—	1.79	0.17	2.3	—
09/13/00		1.34	0.18	—	0.045	0.030	U	0.68	0.11	—	2.05	0.33	2.0	—
10/18/00		1.32	0.11	—	0.046	0.012	—	0.65	0.06	—	1.95	0.19	2.0	14.0
01/17/01		1.15	0.14	—	0.015	0.021	U	0.45	0.07	—	1.34	0.22	2.6	—
04/16/01		1.32	0.11	—	0.048	0.010	—	0.62	0.06	—	1.86	0.17	2.1	12.8
09/25/01		1.34	0.12	—	0.019	0.014	U	0.60	0.07	—	1.78	0.20	2.2	—
12/11/01		1.34	0.11	—	0.035	0.010	—	0.56	0.06	—	1.69	0.16	2.4	16.3
02/19/02		1.32	0.11	—	0.063	0.013	—	0.58	0.05	—	1.76	0.16	2.3	9.2
02/19/02		1.28	0.10	—	0.048	0.012	—	0.59	0.05	—	1.77	0.16	2.2	12.3
05/15/02		1.37	0.11	—	0.033	0.014	UJ	0.67	0.06	—	2.00	0.19	2.1	—
09/11/02		1.22	0.12	—	0.057	0.019	—	0.54	0.06	—	1.63	0.19	2.3	9.4
11/12/02		1.39	0.12	—	0.024	0.011	UJ	0.52	0.05	—	1.57	0.15	2.7	—
02/03/03		1.38	0.11	—	0.048	0.011	—	0.65	0.06	—	1.94	0.17	2.1	13.5
04/29/03		1.28	0.11	—	0.088	0.016	—	0.56	0.05	—	1.71	0.16	2.3	6.4
08/05/03		1.41	0.13	—	0.021	0.014	U	0.64	0.07	—	1.92	0.21	2.2	—
12/01/03		1.28	0.12	—	0.106	0.024	—	0.66	0.07	—	2.02	0.21	1.9	6.3
01/20/04		1.38	0.13	—	0.162 ^a	0.033 ^a	—	0.68	0.08	—	2.10	0.24	2.0	—
05/05/04		1.27	0.12	—	0.042	0.016	J	0.59	0.07	—	1.77	0.20	2.2	—
11/23/04		1.32	0.08	—	0.023	0.011	U	0.70	0.05	—	2.08	0.15	1.9	—
11/23/04		1.27	0.08	—	0.037	0.011	—	0.62	0.05	—	1.87	0.14	2.0	16.7
05/03/05		1.29	0.09	—	0.076	0.018	—	0.69	0.06	—	2.08	0.18	1.9	9.1
05/03/05		1.21	0.09	—	0.082	0.020	—	0.55	0.05	—	1.68	0.16	2.2	6.7
05/11/98	M10S	0.73	0.07	—	0.023	0.007	UJ	0.42	0.04	—	1.27	0.13	1.7	—
07/06/98		0.93	0.09	—	0.045	0.015	—	0.46	0.05	—	1.38	0.16	2.0	10.1
10/07/98		0.72	0.08	J	0.019	0.010	UJ	0.38	0.05	J	1.14	0.14	1.9	—

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
01/13/99		0.79	0.07	J	0.021	0.008	J	0.35	0.04	—	1.06	0.12	2.2	—
04/05/99		0.66	0.06	—	0.017	0.008	UJ	0.27	0.03	—	0.82	0.10	2.4	—
07/13/99		0.71	0.09	—	0.027	0.016	U	0.32	0.05	—	0.96	0.15	2.2	—
10/07/99		0.79	0.08	—	0.019	0.008	J	0.35	0.04	—	1.06	0.13	2.2	—
03/21/00		0.57	0.05	—	0.021	0.006	UJ	0.28	0.03	—	0.83	0.08	2.1	—
07/13/00		0.58	0.06	—	0.016	0.007	J	0.29	0.03	—	0.87	0.10	2.0	—
09/18/00		0.63	0.09	—	0.022	0.014	U	0.33	0.06	—	0.98	0.18	1.9	—
10/18/00		0.84	0.07	—	0.030	0.009	—	0.37	0.04	—	1.12	0.12	2.2	12.6
07/08/98	M11S	1.33	0.14	—	0.079	0.025	—	0.66	0.08	—	2.01	0.25	2.0	8.4
10/08/98		1.34	0.13	J	0.045	0.017	J	0.62	0.07	J	1.85	0.21	2.2	—
01/14/99		1.21	0.10	J	0.024	0.009	J	0.53	0.05	—	1.58	0.16	2.3	—
04/07/99		1.37	0.11	—	0.041	0.011	—	0.55	0.05	—	1.65	0.16	2.5	13.6
07/14/99		1.26	0.11	—	0.036	0.011	—	0.52	0.05	—	1.55	0.15	2.4	14.4
10/06/99		1.24	0.11	—	0.016	0.009	—	0.50	0.05	—	1.48	0.15	2.5	—
03/22/00		1.27	0.09	—	0.058	0.010	J	0.57	0.05	—	1.71	0.14	2.2	9.7
07/12/00		1.17	0.10	—	0.020	0.007	Jdk ^b	0.47	0.05	—	1.40	0.14	2.5	—
09/12/00		1.20	0.16	—	0.030	0.018	U	0.47	0.08	—	1.40	0.24	2.6	—
10/17/00		1.16	0.09	—	0.029	0.008	—	0.44	0.04	—	1.31	0.12	2.7	15.0
01/17/01		1.14	0.14	—	0.034	0.020	U	0.49	0.08	—	1.46	0.23	2.3	—
04/16/01		1.13	0.09	—	0.027	0.008	—	0.42	0.04	—	1.26	0.12	2.7	15.8
09/24/01		1.20	0.11	—	0.084	0.022	—	0.44	0.05	—	1.35	0.16	2.7	5.3
12/04/01		1.17	0.11	—	0.061	0.016	—	0.47	0.06	—	1.43	0.16	2.5	7.8
02/26/02		1.27	0.10	—	0.052	0.012	—	0.54	0.05	—	1.62	0.15	2.4	10.4
09/10/02		1.30	0.13	—	0.047	0.018	J	0.61	0.07	—	1.83	0.22	2.1	—
11/12/02		1.27	0.10	—	0.032	0.011	J	0.47	0.05	—	1.42	0.14	2.7	—
08/04/03		1.19	0.12	—	0.013	0.012	U	0.43	0.06	—	1.30	0.18	2.7	—

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
12/01/03		1.29	0.11	—	0.099	0.020	—	0.53	0.06	—	1.62	0.17	2.4	5.4
01/19/04		1.27	0.11	—	0.086	0.019	—	0.50	0.05	—	1.51	0.16	2.6	5.8
05/05/04		1.15	0.10	—	0.043	0.014	—	0.55	0.06	—	1.64	0.17	2.1	12.8
11/29/04		1.20	0.07	—	0.018	0.008	UJ	0.44	0.04	—	1.33	0.11	2.7	—
04/26/05		1.35	0.11	—	0.052	0.016	—	0.56	0.06	—	1.70	0.17	2.4	10.8
07/08/98	M12S	1.43	0.14	—	0.082	0.026	—	0.72	0.09	—	2.18	0.26	2.0	8.8
10/08/98		1.27	0.13	J	0.016	0.009	UJ	0.49	0.06	J	1.47	0.19	2.6	—
01/13/99		1.39	0.12	J	0.040	0.012	—	0.75	0.07	—	2.25	0.21	1.9	18.9
04/07/99		1.54	0.13	—	0.044	0.012	—	0.72	0.07	—	2.15	0.20	2.2	16.4
05/15/99		1.28	0.13	—	0.023	0.013	U	0.61	0.08	—	1.83	0.22	2.1	—
10/04/99		1.38	0.12	—	0.034	0.011	—	0.64	0.06	—	1.91	0.19	2.2	18.7
03/22/00		1.31	0.09	—	0.061	0.011	J	0.61	0.05	—	1.83	0.14	2.2	9.9
07/12/00		1.34	0.11	—	0.031	0.010	—	0.62	0.06	—	1.85	0.18	2.2	19.7
09/13/00		1.44	0.18	—	0.022	0.014	U	0.68	0.10	—	2.04	0.29	2.1	—
01/22/01		1.64	0.18	—	0.003	0.014	U	0.58	0.09	—	1.71	0.25	2.8	—
04/17/01		1.38	0.11	—	0.062	0.014	—	0.67	0.06	—	2.01	0.18	2.1	10.8
09/24/01		1.43	0.12	—	0.078	0.018	—	0.64	0.06	—	1.95	0.19	2.2	8.3
12/12/01		1.46	0.12	—	0.012	0.008	U	0.60	0.06	—	1.79	0.18	2.4	—
02/26/02		1.29	0.10	—	0.054	0.011	—	0.60	0.05	—	1.82	0.16	2.1	11.2
05/20/02		1.40	0.12	—	0.035	0.017	UJ	0.54	0.06	—	1.63	0.17	2.6	—
09/10/02		1.35	0.11	—	0.079	0.017	—	0.62	0.06	—	1.88	0.17	2.2	7.9
09/10/02		1.44	0.12	—	0.047	0.012	—	0.61	0.06	—	1.85	0.18	2.3	13.1
11/05/02		1.52	0.13	—	0.106	0.020	—	0.67	0.06	—	2.03	0.19	2.3	6.3
02/03/03		1.54	0.12	—	0.033	0.011	—	0.73	0.06	—	2.18	0.19	2.1	21.8
04/29/03		1.30	0.11	—	0.105	0.019	—	0.57	0.05	—	1.75	0.16	2.3	5.4
08/04/03		1.59	0.15	—	0.116	0.028	—	0.61	0.07	—	1.86	0.22	2.6	5.2

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
12/01/03		1.42	0.11	—	0.127	0.020	—	0.64	0.06	—	1.96	0.17	2.2	5.0
01/20/04		1.45	0.14	—	0.118	0.030	—	0.71	0.08	—	2.15	0.25	2.1	6.0
04/26/04		1.52	0.14	—	0.223 ^a	0.037 ^a	—	0.58	0.07	—	—	—	2.6	—
11/29/04		1.45	0.12	—	0.039	0.015	J	0.73	0.07	—	2.18	0.22	2.0	18.6
04/26/05		1.65	0.12	—	0.089	0.022	—	0.65	0.06	—	1.97	0.19	2.5	7.3
07/08/98	M13S	1.38	0.12	—	0.049	0.016	—	0.69	0.07	—	2.06	0.21	2.0	14.1
10/07/98		1.47	0.15	J	0.025	0.015	UJ	0.51	0.07	J	1.52	0.20	2.9	—
01/14/99		1.19	0.10	J	0.044	0.012	—	0.54	0.05	—	1.61	0.16	2.2	12.2
04/07/99		1.36	0.11	—	0.018	0.008	UJ	0.54	0.05	—	1.61	0.16	2.5	—
07/14/99		1.48	0.15	—	0.046	0.017	J	0.55	0.07	—	1.67	0.21	2.7	—
10/05/99		1.21	0.10	—	0.015	0.006	J	0.48	0.05	—	1.44	0.15	2.5	—
03/22/00		1.32	0.09	—	0.057	0.010	J	0.55	0.04	—	1.67	0.13	2.4	9.6
07/12/00		1.24	0.11	—	0.025	0.015	U	0.56	0.06	—	1.68	0.18	2.2	—
09/18/00		1.28	0.16	—	0.033	0.020	U	0.61	0.09	—	1.83	0.28	2.1	—
10/17/00		1.21	0.10	—	0.044	0.012	—	0.51	0.05	—	1.54	0.15	2.4	11.7
01/24/01		1.09	0.16	—	0.074	0.034	UJ	0.54	0.10	—	1.64	0.29	2.0	—
04/17/01		1.25	0.10	—	0.035	0.009	—	0.49	0.05	—	1.46	0.14	2.6	14.0
09/24/01		3.68 ^a	0.31 ^a	—	0.268 ^a	0.050 ^a	—	1.71 ^a	0.16 ^a	—	—	—	—	—
12/11/01		1.27	0.11	—	0.025	0.010	J	0.54	0.06	—	1.61	0.17	2.4	—
02/26/02		1.24	0.10	—	0.052	0.012	—	0.54	0.05	—	1.63	0.15	2.3	10.5
05/20/02		1.38	0.12	—	0.098	0.021	—	0.54	0.06	—	1.64	0.17	2.6	5.5
05/20/02		1.33	0.11	—	0.031	0.011	J	0.59	0.06	—	1.78	0.18	2.2	—
09/11/02		1.35	0.12	—	0.024	0.011	UJ	0.63	0.06	—	1.88	0.19	2.2	—
11/12/02		1.35	0.11	—	0.035	0.011	—	0.58	0.05	—	1.74	0.16	2.3	16.4
11/12/02		1.41	0.12	—	0.036	0.014	UJ	0.60	0.06	—	1.81	0.18	2.3	—
02/03/03		1.41	0.11	—	0.041	0.010	—	0.58	0.05	—	1.74	0.16	2.4	14.2

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
04/29/03		1.26	0.10	—	0.071	0.014	—	0.52	0.05	—	1.56	0.15	2.4	7.2
08/04/03		1.41	0.14	—	0.038	0.017	UJ	0.62	0.08	—	1.85	0.22	2.3	—
12/01/03		1.29	0.10	—	0.104	0.016	—	0.56	0.05	—	1.71	0.14	2.3	5.4
01/28/04		1.21	0.12	—	0.076	0.022	—	0.68	0.08	—	2.04	0.23	1.8	8.9
05/04/04		1.38	0.13	—	0.144 ^a	0.029 ^a	—	0.60	0.07	—	1.84	0.20	2.3	—
11/29/04		1.31	0.09	—	0.036	0.012	J	0.61	0.06	—	1.83	0.16	2.2	—
04/26/05		1.24	0.09	—	0.089	0.020	—	0.66	0.06	—	1.99	0.17	1.9	7.3
07/07/98	M14S	1.29	0.14	—	0.039	0.018	Jdk ^b	0.58	0.08	—	1.74	0.23	2.2	—
10/07/98		1.52	0.14	J	0.031	0.013	UJ	0.73	0.08	J	2.20	0.23	2.1	—
01/13/99		1.39	0.12	J	0.071	0.016	—	0.63	0.06	—	1.89	0.18	2.2	8.9
04/05/99		1.51	0.13	—	0.051	0.015	—	0.71	0.07	—	2.13	0.20	2.1	14.0
07/14/99		1.24	0.13	—	0.030	0.014	U	0.65	0.08	—	1.94	0.23	1.9	—
10/04/99		1.43	0.12	—	0.030	0.010	—	0.60	0.06	—	1.81	0.18	2.4	20.2
03/22/00		1.47	0.10	—	0.052	0.010	J	0.62	0.05	—	1.87	0.15	2.4	11.8
07/12/00		1.36	0.11	—	0.039	0.012	—	0.58	0.06	—	1.73	0.17	2.4	14.7
09/12/00		1.56	0.20	—	0.021	0.017	U	0.67	0.11	—	1.99	0.32	2.3	—
10/17/00		1.69	0.15	—	0.064	0.018	—	0.71	0.07	—	2.13	0.22	2.4	11.1
01/15/01		1.27	0.15	—	0.052	0.023	UJ	0.58	0.08	—	1.76	0.25	2.2	—
04/17/01		1.27	0.10	—	0.046	0.012	—	0.60	0.05	—	1.80	0.16	2.1	13.1
09/25/01		4.29 ^a	0.36 ^a	—	0.117	0.045	—	2.12 ^a	0.20 ^a	—	—	—	—	—
12/12/01		1.40	0.12	—	0.026	0.020	U	0.65	0.07	—	1.95	0.20	2.2	—
02/25/02		1.43	0.11	—	0.055	0.011	—	0.60	0.05	—	1.82	0.16	2.4	11.1
05/15/02		1.58	0.13	—	0.029	0.013	UJ	0.61	0.06	—	1.82	0.19	2.6	—
09/10/02		1.49	0.13	—	0.070	0.019	—	0.71	0.07	—	2.13	0.21	2.1	10.2
11/05/02		1.51	0.12	—	0.027	0.012	UJ	0.65	0.06	—	1.94	0.18	2.3	—
02/03/03		1.55	0.12	—	0.102	0.019	—	0.62	0.06	—	1.88	0.17	2.5	6.0

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
02/03/03		1.46	0.12	—	0.029	0.012	UJ	0.68	0.06	—	2.02	0.19	2.2	—
04/28/03		1.34	0.11	—	0.061	0.015	—	0.66	0.06	—	1.98	0.18	2.0	10.7
08/05/03		1.45	0.15	—	0.073	0.022	—	0.67	0.08	—	2.03	0.25	2.2	9.2
12/01/03		1.46	0.13	—	0.083	0.021	—	0.63	0.06	—	1.92	0.19	2.3	7.7
01/26/04		1.51	0.14	—	0.088	0.022	—	0.59	0.07	—	1.80	0.20	2.6	6.8
04/26/04		1.39	0.12	—	0.216 ^a	0.035 ^a	—	0.57	0.06	—	1.80	0.19	2.4	—
11/30/04		1.58	0.13	—	0.062	0.018	—	0.82	0.08	—	2.46	0.23	1.9	13.3
04/27/05		1.28	0.09	—	0.110	0.023	—	0.71	0.06	—	2.16	0.19	1.8	6.4
03/20/00	M15S	1.07	0.08	—	0.031	0.007	UJ	0.57	0.05	—	1.72	0.14	1.9	—
07/12/00		1.10	0.10	—	0.014	0.010	U	0.50	0.05	—	1.49	0.15	2.2	—
09/19/00		1.23	0.16	—	0.050	0.022	J	0.55	0.09	—	1.66	0.26	2.2	—
10/18/00		0.84	0.07	—	0.020	0.006	—	0.39	0.04	—	1.17	0.12	2.1	19.5
01/16/01		1.14	0.14	—	0.055	0.024	J	0.51	0.08	—	1.54	0.24	2.2	—
04/18/01		1.22	0.10	—	0.055	0.013	—	0.56	0.05	—	1.68	0.16	2.2	10.1
09/19/01		1.13	0.11	—	0.059	0.018	—	0.50	0.06	—	1.51	0.18	2.3	8.5
11/28/01		1.24	0.11	—	0.036	0.012	J	0.54	0.06	—	1.63	0.18	2.3	—
02/25/02		1.21	0.10	—	0.076	0.014	—	0.51	0.05	—	1.56	0.14	2.4	6.7
05/14/02		1.11	0.09	—	0.051	0.013	—	0.58	0.06	—	1.76	0.16	1.9	11.4
09/16/02		1.08	0.10	—	0.042	0.016	UJ	0.49	0.05	—	1.47	0.16	2.2	—
11/06/02		1.17	0.10	—	0.039	0.012	—	0.58	0.06	—	1.75	0.17	2.0	14.7
02/04/03		1.05	0.09	—	0.036	0.011	—	0.57	0.06	—	1.72	0.17	1.8	15.8
05/06/03		1.08	0.09	—	0.107	0.019	—	0.49	0.05	—	1.52	0.14	2.2	4.6
05/06/03		1.09	0.09	—	0.055	0.014	—	0.55	0.05	—	1.65	0.15	2.0	9.9
08/05/03		1.17	0.11	—	0.091	0.022	—	0.66	0.07	—	2.02	0.22	1.8	7.3
08/05/03		1.27	0.12	—	0.260 ^a	0.043 ^a	—	0.56	0.07	—	1.78	0.21	2.3	—
12/03/03		1.08	0.08	—	0.109	0.017	—	0.54	0.05	—	1.66	0.14	2.0	5.0

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
01/27/04		1.10	0.11	—	0.053	0.019	—	0.59	0.07	—	1.78	0.20	1.9	—
05/04/04		1.24	0.12	—	0.082	0.023	—	0.49	0.06	—	1.49	0.18	2.5	6.0
10/29/04		1.29	0.10	—	0.044	0.015	J	0.58	0.06	—	1.76	0.17	2.2	—
10/29/04		1.23	0.10	—	0.031	0.013	UJ	0.66	0.06	—	1.97	0.19	1.9	—
05/04/05		1.13	0.09	—	0.060	0.018	—	0.55	0.05	—	1.65	0.16	2.1	9.1
03/20/00	M16S	1.38	0.10	—	0.040	0.009	UJ	0.66	0.05	—	1.97	0.16	2.1	—
07/19/00		1.26	0.11	—	0.040	0.012	—	0.58	0.06	—	1.74	0.18	2.2	14.4
09/18/00		1.31	0.16	—	0.029	0.020	U	0.60	0.09	—	1.80	0.27	2.2	—
10/18/00		1.28	0.11	—	0.033	0.013	Jdk ^b	0.59	0.06	—	1.76	0.18	2.2	—
01/17/01		1.23	0.15	—	0.070	0.025	J	0.63	0.09	—	1.90	0.27	2.0	—
04/23/01		1.19	0.11	—	0.113	0.024	—	0.53	0.06	—	1.63	0.18	2.2	4.7
09/20/01		1.30	0.12	—	0.045	0.017	—	0.64	0.07	—	1.92	0.21	2.0	—
12/04/01		1.30	0.12	—	0.022	0.016	U	0.62	0.07	—	1.86	0.21	2.1	—
02/27/02		1.21	0.10	—	0.023	0.009	UJ	0.67	0.06	—	1.99	0.18	1.8	—
05/15/02		1.42	0.12	—	0.053	0.013	—	0.65	0.06	—	1.96	0.19	2.2	12.2
09/18/02		1.59	0.14	—	0.063	0.017	—	0.89	0.08	—	2.69	0.25	1.8	14.1
11/11/02		1.26	0.10	—	0.028	0.010	UJ	0.59	0.06	—	1.75	0.16	2.2	—
02/04/03		1.27	0.11	—	0.046	0.012	—	0.65	0.06	—	1.96	0.18	2.0	14.3
04/30/03		1.26	0.11	—	0.147	0.023	—	0.56	0.05	—	1.72	0.16	2.3	3.8
08/04/03		1.40	0.13	—	0.090	0.022	—	0.58	0.07	—	1.76	0.20	2.4	6.4
12/01/03		1.31	0.12	—	0.063	0.018	—	0.58	0.06	—	1.75	0.18	2.3	9.2
01/21/04		1.30	0.12	—	0.042	0.014	—	0.65	0.07	—	1.96	0.21	2.0	—
05/04/04		1.34	0.12	—	0.135	0.029	—	0.59	0.07	—	1.81	0.20	2.3	4.4
05/04/04		1.25	0.11	—	0.140	0.026	—	0.63	0.07	—	1.95	0.20	2.0	4.5
11/30/04		1.58	0.13	—	0.062	0.018	—	0.82	0.08	—	2.46	0.23	1.9	13.3
05/04/05		1.30	0.10	—	0.070	0.019	—	0.71	0.07	—	2.14	0.19	1.8	10.1

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
07/24/00	M17S	1.13	0.10	—	0.029	0.011	J	0.52	0.06	—	1.57	0.17	2.2	—
09/20/00		1.31	0.17	—	0.037	0.025	U	0.58	0.10	—	1.75	0.28	2.2	—
10/24/00		1.23	0.10	—	0.041	0.011	—	0.60	0.06	—	1.80	0.17	2.1	14.8
02/02/01		1.19	0.16	—	0.007	0.015	U	0.63	0.11	—	1.87	0.32	1.9	—
04/18/01		1.20	0.10	—	0.044	0.010	—	0.51	0.05	—	1.55	0.15	2.3	11.7
09/09/01		1.13	0.11	—	0.020	0.014	U	0.48	0.06	—	1.42	0.18	2.4	—
11/28/01		1.25	0.11	—	0.077	0.018	—	0.70	0.07	—	2.11	0.21	1.8	9.1
02/20/02		1.21	0.10	—	0.071	0.013	—	0.51	0.05	—	1.56	0.14	2.4	7.3
05/14/02		1.28	0.11	—	0.030	0.013	UJ	0.60	0.06	—	1.80	0.18	2.1	—
09/17/02		1.26	0.11	—	0.069	0.015	—	0.63	0.06	—	1.91	0.19	2.0	9.1
11/06/02		1.18	0.10	—	0.005	0.006	U	0.59	0.06	—	1.75	0.17	2.0	—
02/04/03		1.19	0.10	—	0.051	0.017	J	0.51	0.05	—	1.55	0.15	2.3	—
05/07/03		1.10	0.09	—	0.103	0.018	—	0.51	0.05	—	1.57	0.15	2.1	5.0
08/06/03		1.15	0.12	—	0.109	0.026	—	0.53	0.07	—	1.63	0.20	2.2	4.9
12/03/03		1.13	0.10	—	0.075	0.018	—	0.54	0.06	—	1.63	0.17	2.1	7.1
01/21/04		1.27	0.12	—	0.054	0.019	—	0.54	0.07	—	1.63	0.19	2.4	—
10/29/04		1.10	0.09	—	0.049	0.016	—	0.56	0.06	—	1.68	0.17	2.0	11.5
10/29/04		1.10	0.09	—	0.043	0.015	J	0.61	0.06	—	1.85	0.19	1.8	—
05/05/05		1.16	0.09	—	0.046	0.015	—	0.46	0.05	—	1.40	0.15	2.5	10.1
05/05/05		1.10	0.09	—	0.118	0.025	—	0.56	0.06	—	1.71	0.17	2.0	4.7
10/19/00	A11A31	0.90	0.08	—	0.046	0.010	—	0.41	0.04	—	1.24	0.12	2.2	9.0
01/15/01		0.92	0.12	—	0.023	0.017	U	0.48	0.08	—	1.44	0.23	1.9	—
04/23/01		1.19	0.11	—	0.041	0.011	UJ	0.54	0.06	—	1.61	0.17	2.2	—
12/04/01		0.95	0.09	—	0.068	0.023	—	0.41	0.05	—	1.26	0.16	2.3	6.1
02/25/02		0.94	0.08	—	0.025	0.009	J	0.44	0.04	—	1.32	0.13	2.1	17.6
05/21/02		1.38	0.12	—	0.068	0.017	—	0.64	0.07	—	1.95	0.19	2.1	9.5

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
09/16/02		1.22	0.11	—	0.040	0.012	—	0.53	0.05	—	1.58	0.16	2.3	13.3
11/05/02		1.21	0.10	—	0.033	0.012	J	0.60	0.06	—	1.79	0.17	2.0	18.4
02/03/03		1.65	0.13	—	0.049	0.010	—	0.81	0.07	—	2.43	0.21	2.0	16.5
04/30/03		1.22	0.09	—	0.084	0.014	—	0.53	0.05	—	1.62	0.14	2.3	6.3
08/04/03		1.59	0.15	—	0.084	0.023	—	0.90	0.10	—	2.72	0.29	1.8	10.7
12/02/03		1.47	0.13	—	0.064	0.017	—	0.65	0.07	—	1.97	0.20	2.3	10.2
01/20/04		1.56	0.13	—	0.048	0.016	—	0.78	0.08	—	2.34	0.23	2.0	16.4
04/26/04		1.10	0.12	—	0.129 ^a	0.035 ^a	—	0.57	0.08	—	1.74	0.23	1.9	—
11/22/04		1.35	0.08	—	0.023	0.008	—	0.62	0.05	—	1.85	0.14	2.2	26.9
04/25/05		1.38	0.10	—	0.043	0.015	J	0.60	0.06	—	1.79	0.18	2.3	—
09/19/00	USGS-127	0.99	0.14	—	0.032	0.018	U	0.49	0.09	—	1.48	0.25	2.0	—
10/18/00		1.02	0.08	—	0.029	0.008	—	0.57	0.05	—	1.70	0.15	1.8	19.8
01/18/01		1.05	0.13	—	0.024	0.018	U	0.64	0.09	—	1.92	0.27	1.6	—
04/24/01		0.97	0.08	—	0.029	0.010	—	0.50	0.05	—	1.49	0.14	2.0	17.0
09/18/01		1.03	0.10	—	0.017	0.012	U	0.47	0.06	—	1.41	0.18	2.2	—
12/06/01		1.03	0.10	—	0.057	0.017	—	0.44	0.05	—	1.32	0.16	2.4	7.6
02/27/02		0.99	0.08	—	0.042	0.010	—	0.50	0.05	—	1.49	0.13	2.0	11.9
05/21/02		1.00	0.09	—	0.035	0.015	UJ	0.59	0.06	—	1.77	0.19	1.7	—
09/18/02		1.14	0.10	—	0.026	0.013	UJ	0.58	0.06	—	1.74	0.17	2.0	—
11/11/02		1.04	0.09	—	0.053	0.012	—	0.50	0.05	—	1.52	0.15	2.1	9.5
02/04/03		1.06	0.09	—	0.018	0.008	UJ	0.52	0.05	—	1.56	0.15	2.0	—
05/05/03		1.10	0.08	—	0.046	0.010	—	0.51	0.04	—	1.54	0.13	2.2	11.1
08/04/03		1.06	0.10	—	0.010	0.009	U	0.51	0.06	—	1.53	0.18	2.1	—
12/03/03		1.13	0.09	—	0.087	0.016	—	0.49	0.05	—	1.50	0.14	2.3	5.7
01/28/04		1.08	0.10	—	0.049	0.017	—	0.49	0.06	—	1.47	0.17	2.2	—
05/05/04		1.22	0.11	—	0.080	0.022	—	0.44	0.05	—	1.33	0.16	2.8	5.4

Table 3-67. (continued).

Date Sampled	Aquifer Well	U-234 (pCi/L)	1σ (pCi/L)	Flag	U-235 (pCi/L)	1σ (pCi/L)	Flag	U-238 (pCi/L)	1σ (pCi/L)	Flag	Total Uranium (μg/L)	1σ (μg/L)	U-234:U-238 Ratios	U-238:U-235 Ratios
12/02/04		0.97	0.08	—	0.035	0.013	J	0.54	0.06	—	1.61	0.17	1.8	—
04/28/05		1.08	0.09	—	0.041	0.015	J	0.52	0.06	—	1.57	0.17	2.1	—
Mean:		1.17	0.11	—	0.046	0.014	—	0.54	0.06	—	1.61	0.18	2.18	10.9
Standard Deviation:		0.29			0.028			0.13			0.39		0.25	4.7
Minimum:		0.38			0.001			0.17			0.50		1.40	3.6
Maximum:		1.69			0.147^c			0.90			2.72		3.23	26.9
Upper Tolerance Limit:		1.92^d			NA			0.90^d			NA		NA	NA
Mean + 3 std dev:		2.03			0.130			0.92			2.79		2.95	24.9

Note: Results shown in **bold font** are positive detections (i.e., $>3\sigma$ and $>$ minimum detectable concentration).

a. Values determined to be within-well statistical outliers.

b. Jdk indicates this data-qualifier flag is project-assigned.

c. Value is the maximum concentration and is used as the upper limit value to evaluate U-235 in aquifer samples.

d. Values are statistically derived upper tolerance limits used to evaluate U-234 and -238 in aquifer samples (Leecaster, Koeppen, and Olson 2003). Upper tolerance limit for U-235 was not established because most U-235 data are nondetections and yield large statistical variances.

Values are background upper limit values used to evaluate uranium in soil-moisture samples.

3.12.2 Buried Waste Inventory

Approximately 2.10 Ci of U-233, 63.5 Ci of U-234, 4.88 Ci of U-235, 1.43 Ci of U-236, and 141 Ci of U-238 were buried in the SDA through 1999. An additional 0.0174 Ci of U-233, 0.407 Ci of U-234, 0.0382 Ci of U-235, 0.0175 Ci of U-236, and 7.39 Ci of U-238 are projected to be added by 2009, for totals of 2.12 Ci of U-233, 63.9 Ci of U-234, 4.92 Ci of U-235, 1.45 Ci of U-236, and 148 Ci of U-238. Most of the uranium is from weapons manufacturing waste, but INL Site operations also contributed a substantial portion (Holdren et al. 2006).

3.12.3 Vadose Zone

The following subsections discuss distribution of uranium isotopes in vadose zone core, soil-moisture, and perched water samples in various depth intervals.

3.12.3.1 Lysimeter Samples at Depths from 0 to 35 ft. In FY 2005, 33 U-233/234, U-235/236, and U-238 analyses were performed on soil-moisture samples collected from 14 shallow lysimeters near RWMC. Soil-moisture concentrations in the 0 to 35-ft depth range that exceeded upper background concentration levels were 55% (18) of the U-233/234, 24% (eight) of the U-235/236, and 61% (20) of the U-238. To compare measured concentrations to the drinking water MCL, isotopic uranium results were converted from activity (pCi/L) to mass ($\mu\text{g/L}$) and summed; 39% (13) of shallow-depth uranium results performed in FY 2005 exceeded the total uranium MCL of 30 $\mu\text{g/L}$. In FY 2005, analyses results exceeding the MCL involved seven lysimeter locations, six of which (i.e., PA01:L15, PA02:L16, PA03:L33, W08:L13, W23:L07, and W23:L09) have a long history of concentrations above the MCL. Table 3-68 presents isotopic uranium analyses results exceeding local soil-moisture upper background concentrations, including the calculated total uranium concentration and MCL exceedances. Section 3.12.5 presents a summary of concentration ranges, detection frequencies, and exceedances in FY 2005, along with a figure showing the sample locations where uranium was detected above the MCL.

Though concentrations at seven lysimeter locations are above the MCL, concentrations remain relatively stable, except at locations PA02:L16 and W08:L13, where concentrations are decreasing (see Figure 3-18 and 3-19).

Since 1997, 212 U-233/234, U-235/236, and U-238 analyses have been performed on soil-moisture samples collected from 18 shallow lysimeters near RWMC. Concentrations exceeded upper background concentration levels in 66% (139) of the U-233/234 results, 32% (67) of the U-235/236 results, and 70% (149) of the U-238 results. To compare measured concentrations to the MCL, isotopic uranium results were converted from activity (pCi/L) to mass equivalents ($\mu\text{g/L}$) and summed. Almost 50% (104) of shallow uranium results since 1997 exceeded the total uranium MCL of 30 $\mu\text{g/L}$. Concentrations exceeding the MCL between 1997 and August 2005 were detected in nine lysimeters, six of which have a history of concentrations above the MCL (i.e., PA01:L15, PA02:L16, PA03:L33, W08:L13, W23:L07, and W23:L09) (see Tables 3-69, 3-70, and 3-71). Lysimeters with uranium concentrations consistently above upper background levels or the MCL are located in monitoring wells around Pad A (i.e., Wells PA01, PA02, and PA03), the western part of the SDA (i.e., Well W23), and near the Acid Pit (i.e., Well W08). In the Roback et al. (2000) study, using thermal ionization mass spectrometry, samples with uranium concentrations significantly above background (up to 144 ppb) were found to have natural U-238:U-235 isotope ratios, and no U-236 was detected. Most of these samples were interpreted as natural uranium. Thus, natural background concentrations in these areas are higher than in other locations. Section 3.12.5 presents concentration ranges, detection rates, and MCL exceedances since 1997.

Table 3-68. Isotopic uranium concentrations in shallow-depth (0 to 35 ft) lysimeters exceeding local soil-moisture background in Fiscal Year 2005.

Lysimeter	Lysimeter Depth (ft)	Sample Date	Sample Results			Total Uranium ^a	Comparison Concentration
			U-233/234 (pCi/L)	U-235/236 (pCi/L)	U-238 (pCi/L)	Calculated Result ^b (µg/L)	Maximum Contaminant Level ^c (µg/L)
PA01:L15	14.3	11/15/04	40 ± 4	ND	23 ± 3	69 ± 7^d	30
		02/02/05	39 ± 4	ND	26 ± 3	77 ± 8^d	30
		05/25/05	41 ± 4	2.5 ± 0.7	23 ± 2	69 ± 7^d	30
		08/08/05	34 ± 3	3.0 ± 0.8	22 ± 2	66 ± 7^d	30
PA02:L16	8.7	11/15/04	20 ± 2	ND	9.5 ± 1.4	29 ± 4	30
		02/02/05	21 ± 2	ND	10.5 ± 1.5	32 ± 4^d	30
		05/25/05	16.8 ± 1.9	1.4 ± 0.5	8.7 ± 1.2	26 ± 4	30
		08/08/05	10.2 ± 1.4	ND	5.5 ± 0.9	16 ± 3	30
PA03:L33	10	05/24/05	48 ± 3	5.0 ± 0.3	39 ± 3	119 ± 8^d	30
		08/08/05	45 ± 4	1.7 ± 0.6	32 ± 3	97 ± 9^d	30
R1936:DL70	30	05/26/05	—	ND	4.3 ± 0.9	13 ± 3	30
		08/10/05	—	ND	4.3 ± 0.9	13 ± 3	30
W05:L24	15.9	02/02/05	—	4.8 ± 0.5	—	9.5 ± 1.9	30
W08:L13	11.3	05/25/05	11.2 ± 1.5	ND	10.7 ± 1.4	32 ± 4^d	30
		08/08/05	17 ± 2	ND	8.7 ± 1.3	26 ± 4	30
W23:L07	18.8	05/24/05	54 ± 4	2.8 ± 0.6	33 ± 3.0	100 ± 9^d	30
		08/09/05	57 ± 5	2.4 ± 0.7	38 ± 3	113 ± 10^d	30
W23:L09	7.7	05/24/05	45 ± 4	4.8 ± 0.5	30 ± 3	90 ± 8^d	30
		08/09/05	40 ± 4	ND	28 ± 3	83 ± 8^d	30
98-1:L35	16.5	05/25/05	11.1 ± 1.7	4.8 ± 0.5	5.2 ± 1.1	16 ± 3	30
98-5:L39	10.5	08/09/05	20 ± 2	ND	11.5 ± 1.5	35 ± 4^d	30

a. Reported isotopic uranium concentrations (pCi/L) are converted to mass units (µg/L) and summed to compare results to the drinking water MCL.

b. Conversion from activity units (pCi/L) to mass units (µg/L) is performed using the following values:

- U-233/234 pCi/L × 1.6023735E-04 = U-234 µg/L
- U-235/236 pCi/L × 4.6240480E-01 = U-235 µg/L
- U-238 pCi/L × 2.9734887E+00 = U-238 µg/L.

(Note: U-233/234 is assumed to be only U-234, and U-235/236 is assumed to be only U-235.)

c. MCL is from the “National Primary Drinking Water Standards” (40 CFR 141) and pertains to total uranium, not each individual uranium isotope.

d. **Bold font** indicates sample concentrations that exceed MCL (see Footnote c).

MCL = maximum contaminant level

ND = sample result is a nondetection

— = indicates a detection below upper background concentration limits. In Fiscal Year 2005, soil moisture upper background values applied to isotopic uranium results are 8.52 pCi/L for U-233/234, 1.34 pCi/L for U-235/236, and 3.86 pCi/L for U-238.

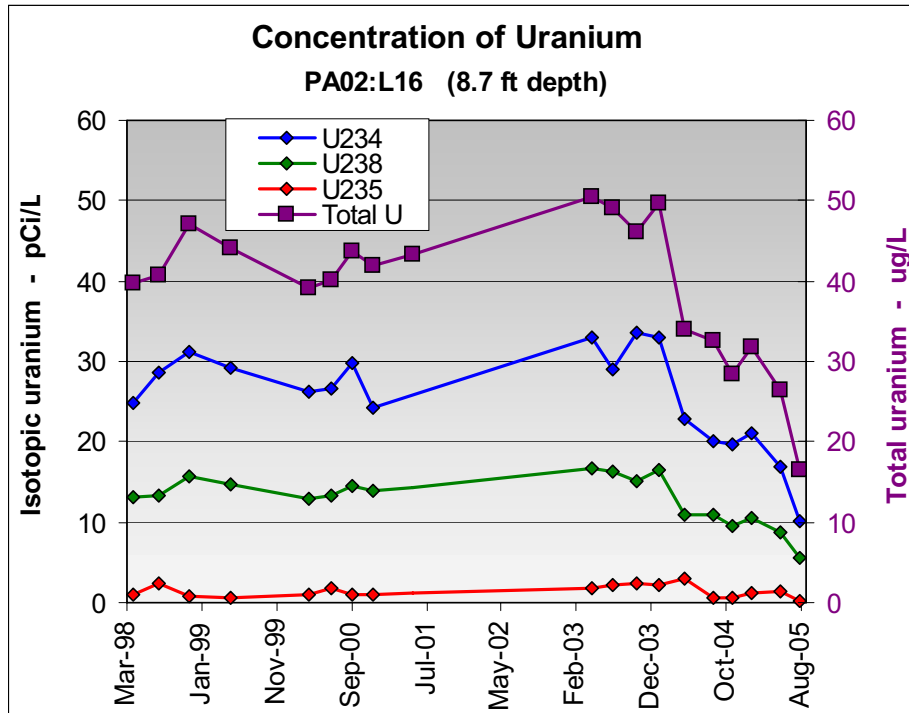


Figure 3-18. Uranium concentrations at Lysimeter PA02:L16 in early Fiscal Year 2004.

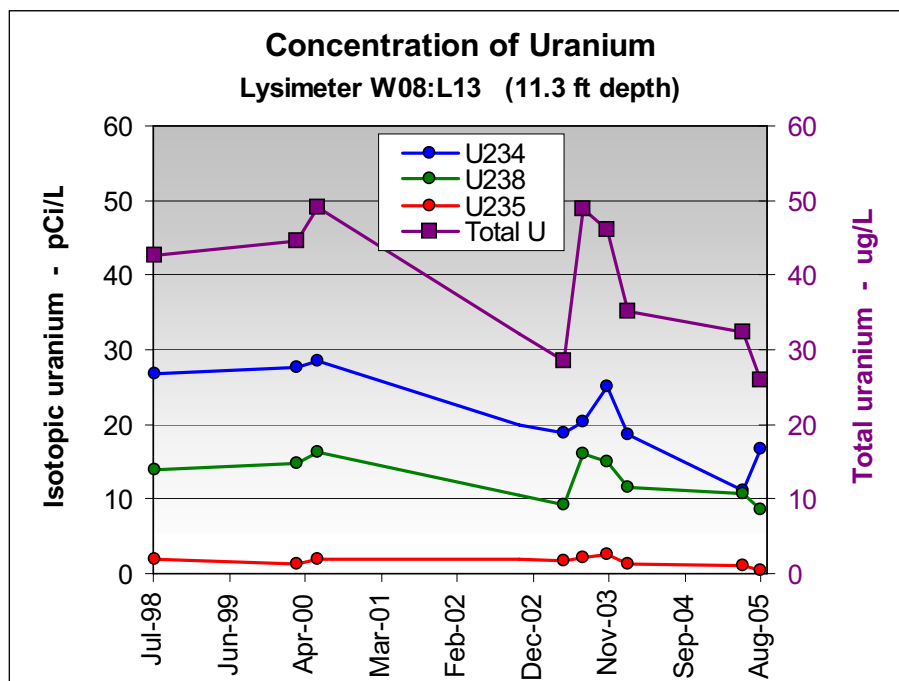


Figure 3-19. Uranium concentrations at Lysimeter W08:L13 in Fiscal Year 2003.

Table 3-69. Uranium-233/234 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Uranium-233/234 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																			
	2																			
	3							43												
	4							35												
1998	1																			
	2							55												
	3	8.7	4.8	6.4		36	25	46												
	4		4.4	8.9		39	29					4.5		27				60	49	3.8
1999	1	10	5.7	11		40	33	57				4.9							50	
	2	10																		
	3	12	4.3	14		36	29	53												
	4																			
2000	1	13						58				5.6								4.6
	2	10	4.5	14		36	26	62						29				71	64	
	3	13	5.2	20		42	28					6.7		30				76	66	4.8
	4	12	6.1	17		40	30													5.2
2001	1						24													
	2																			
	3	9.2	6.2	12		11	5.2				4.4	4.1						87		
	4																			

Table 3-69. (continued).

Uranium-233/234 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2002	1																			
	2																			
	3		2.6			25						125				2.4				4.6
	4					37											68		38	5.7
2003	1		4.1	11	4.1									6.5			84			4.2
	2																			3.3
	3	8.4	2.9	12		34	33							19		2.0	73		63	4.8
	4	13				38	29							20			71		63	
2004	1			10		35	34							25		3.1	85			4.7
	2						33													3.8
	3			1.5			23										72		19	3.5
	4		4.3			44	20							19		4.9	59		55	4.0
2005	1		4.6			40	20									6.2				5.0
	2					39	21			5.5										
	3	11	4.2			41	17	48	3.8				3.1	11		4.4	54		45	4.4
	4		6.0	20		34	10	45	5.1					17			57		40	4.0
Note 1: The highest result is reported for duplicate samples or reanalysis. Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square). MCL = maximum contaminant level For comparison, the maximum contaminant level = 30 µg/L for total uranium.																				
	U-233/234 was analyzed, but not detected.																			
x.xx	U-233/234 was detected at or below local soil-moisture upper background concentration (8.52 pCi/L).																			
	U-233/234 was detected above local soil-moisture upper background, but less than the MCL.																			
	U-233/234 contributed to a detection greater than MCL for total uranium (see Note 2).																			

Table 3-70. Uranium-235/236 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

Uranium-235/236 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																			
	2																			
	3							1.8												
	4							1.6												
1998	1																			
	2							2.6												
	3							1.9												
	4					2.3	2.3							2.0				1.9	1.9	
1999	1		0.37	1.2		1.6	1.1	2.3				0.35							1.7	
	2																			
	3					1.2														
	4																			
2000	1							3.5												
	2			0.76		1.5	1.2	3.0						1.6				3.0	2.9	
	3	1.3		1.6		1.7	2.1					0.84		1.9				2.4	2.7	
	4					1.3														
2001	1																			
	2																			
	3																	3.7		
	4																			
2002	1																			
	2																			
	3											3.7								
	4					3.3											10		6.1	

Table 3-70. (continued).

Uranium-235/236 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																				
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2003	1																2.9			
	2																			
	3					2.5	1.7							1.8			3.1		7.8	
	4					3.1	2.1							2.1			5.3		2.7	
2004	1					4.8	2.5							2.5			4.0			
	2						2.1													
	3						2.9										4.0			
	4																2.8		2.2	
2005	1																			
	2																			
	3					2.5	1.4	5.0									2.8		4.8	
	4					3.0		1.7									2.4			
Note 1: The highest result is reported for duplicate samples or reanalysis. Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square). For comparison, the MCL = 30 µg/L for total uranium. MCL = maximum contaminant level																				
	U-235/236 was analyzed for but not detected.																			
x.xx	U-235/236 was detected at or below local soil moisture upper background concentration (1.34 pCi/L).																			
	U-235/236 was detected above soil moisture upper background, but less than the MCL.																			
	U-235/236 contributed to a detection greater than the MCL for total uranium (see Note 2).																			

Table 3-71. Uranium-238 detections in shallow-depth (0 to 35 ft) lysimeters since 1997.

		Uranium-238 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																		
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																			
	2																			
	3							34												
	4							26												
1998	1																			
	2							40												
	3	4.4	3.3	3.5		20	13	33												
	4		2.9	5.6		21	14					3.3		14				35	27	3.9
1999	1	7.0	3.2	6.3		24	16	41				3.6							29	
	2	6.1																		
	3	7.1	3.5	9.4		21	16	39												
	4																			
2000	1	9.7						42				3.7								3.5
	2	6.9	2.6	11		19	13	44						16				40	37	
	3	8.4	3.0	12		26	14					4.3		16				46	39	3.3
	4	8.8	2.8	9.1		24	15													3.7
2001	1						14													
	2																			
	3	7.7		7.2		7.1	3.6				3.9	3.9						53		
	4																			
2002	1																			
	2																			
	3		1.5			13						53				1.6				2.6
	4					20											40		23	2.5
2003	1		2.0	8.7										2.8			54			2.4
	2																			3.3
	3	7.3	2.1			22	17							9.3		1.8	39		38	2.4
	4	8.1				24	16							16			38		30	

Table 3-71. (continued).

		Uranium-238 Radioactive Waste Management Complex Lysimeters (0 to 35 ft)																		
Fiscal Year	Quarter	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	R1936: DL70	W05: L24	W05: L25	W06: L27	W08: L12	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
2004	1			8.0		16	15							15			51			3.3
	2						16							12						2.2
	3		3.1				11										41		9.4	2.2
	4		2.1			21	11									2.7	37		32	3.4
2005	1		2.7			23	9.5									3.6				2.8
	2					26	11			3.1										
	3	5.2	2.1			23	8.7	39	4.3				1.6	11		3.3	33		30	2.8
	4		2.4	12		22	5.5	32	4.3					8.7			38		28	3.2
Note 1: The highest result is reported for duplicate samples or reanalysis.																				
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																				
For comparison, the MCL = 30 µg/L for total uranium.																				
MCL = maximum contaminant level																				
	U-238 was analyzed for but not detected.																			
x.xx	U-238 was detected at or below local soil moisture upper background concentration (3.86 pCi/L).																			
	U-238 was detected above soil-moisture background, but less than the MCL.																			
	U-238 contributed to a detection greater than the MCL for total uranium (see Note 2).																			

One previous observation in this depth range centered on changes and trends associated with U-238:U-235 activity ratios at some monitoring locations. Activity ratios for U-238:U-235, which are constant in nature, exhibited subtle changes at monitoring locations PA01:L15, PA02:L16, PA03:L33, and W23:L09. The isotopic ratios were used to erroneously conclude that enriched uranium, with a slight U-235 enrichment, was present at these locations. However, revised interpretation of U-238:U-235 and U-234:U-238 ratios indicate the uranium is naturally occurring.

Though isotopic ratios around Pad A, the western end of the SDA, and the Acid Pit are within the range of naturally occurring uranium (Roback et al. 2000), other contaminants are detected in these locations. Presence of these other contaminants, in combination with higher uranium concentrations, could be interpreted as leachate influencing concentrations in these wells. The following points support this interpretation:

- Uranium concentrations are significantly higher at these monitoring locations than all other lysimeters in this depth range
- Pad A contains a substantial portion (approximately 13%) of the total uranium buried in the SDA
- Aqueous waste solutions containing uranium from various INL Site processes were buried in the Acid Pit
- Other constituents often associated with uranium-bearing waste (e.g., from reactor operations) are detected at these locations
- Deep-depth lysimeters around Pad A (i.e., Lysimeters D06:DL01 and D06:DL02) exhibit similar uranium coincident with concentrations of other constituents.

Though concentrations at seven lysimeter locations are greater than the MCL for total uranium, concentrations remain relatively stable in five of the lysimeters, while decreasing in two (i.e., PA02:L16 and W08:L13) (see Figures 3-18 and 3-19).

3.12.3.2 Lysimeter Samples at Depths from 35 to 140 ft. In FY 2005, 39 analyses for U-233/234, U-235/236, and U-238 were performed on soil-moisture samples collected from 14 intermediate-depth lysimeters near RWMC. Soil-moisture concentrations in the 35 to 140-ft depth range that exceeded upper background concentrations were 31% (12) of the U-233/234, 18% (seven) of the U-235/236, and 36% (14) of the U-238. To compare measured concentrations to the drinking water MCL, isotopic uranium results were converted from activity (pCi/L) to mass (µg/L) and summed; approximately 28% (11) of the intermediate-depth uranium results performed in FY 2005 exceeded the total uranium MCL of 30 µg/L. In FY 2005, analyses results exceeding the MCL involved five lysimeter locations, four of which have a long history of concentrations greater than the MCL (i.e., D06:DL01, D06:DL02, I-1S:DL09, and TW1:DL04). Table 3-72 lists isotopic uranium analyses results that exceeded local soil-moisture upper background concentrations, including the calculated total uranium concentration and MCL exceedances. Section 3.12.5 presents a summary of concentration ranges, detection frequencies, and MCL exceedances since 1997.

In FY 2005, concentrations at monitoring wells above the MCL remained relatively constant at location I-1S:DL09, decreased slightly at locations D06:DL01 and D06:DL02, and increased at location TW1:DL04. Figures 3-20, 3-21, and 3-22 present the concentration history of those lysimeters where concentrations changed in FY 2005.

Table 3-72. Isotopic uranium concentrations in intermediate-depth (35 to 140 ft) lysimeters exceeding local soil-moisture background in Fiscal Year 2005.

Lysimeter	Lysimeter Depth (ft)	Sample Date	Sample Result			Total Uranium ^a	Comparison Concentration
			U-233/234 (pCi/L)	U-235/236 (pCi/L)	U-238 (pCi/L)	Calculated Result (μg/L) ^b	Maximum Contaminant Level ^c (μg/L)
D06:DL01	88	11/15/04	88 ± 7	2.8 ± 0.7	49 ± 4	146 ± 12^d	30
		05/25/05	82 ± 5	4.9 ± 1.0	43 ± 3	129 ± 10^d	30
		08/08/05	48 ± 4	ND	29 ± 3	85 ± 8^d	30
D06:DL02	44	11/15/04	100 ± 8	5.2 ± 1.0	39 ± 4	119 ± 11^d	30
		05/25/05	87 ± 7	4.4 ± 0.8	40 ± 4	120 ± 11^d	30
		08/08/05	84 ± 7	2.2 ± 0.7	41 ± 4	122 ± 11^d	30
I-1S:DL09	101	11/15/04	18 ± 2	ND	11.5 ± 1.5	35 ± 5^d	30
		02/07/05	15.7 ± 1.7	ND	10.1 ± 1.3	30 ± 4^d	30
I-4S:DL15	97	11/15/04	10.5 ± 1.4	ND	—	9 ± 2	30
		02/02/05	—	ND	4.3 ± 0.8	13 ± 2	30
		05/25/05	—	ND	5.2 ± 0.9	16 ± 3	30
		08/08/05	—	ND	4.5 ± 0.8	14 ± 2	30
R1935:DL60	96	05/26/05	12.3 ± 1.5	ND	11.3 ± 1.4	34 ± 4^d	30
		08/10/05	10.6 ± 1.5	2.4 ± 0.7	10.5 ± 1.5	32 ± 4^d	30
R2004:DL50	74	05/25/05	—	2.8 ± 0.9	—	9 ± 2	30
TW1:DL04	101.7	05/24/05	98 ± 8	9.5 ± 0.9	12.0 ± 1.6	40 ± 5^d	30

a. Reported isotopic uranium concentrations (pCi/L) are converted to mass units (μg/L) and summed in order to compare results to the drinking water MCL.

b. Conversion from activity units (pCi/L) to mass units (μg/L) are performed using the following values:

- U-233/234 pCi/L × 1.6023735E-04 = U-234 μg/L
- U-235/236 pCi/L × 4.6240480E-01 = U-235 μg/L
- U-238 pCi/L × 2.9734887E+00 = U-238 μg/L.

(Note: U-233/234 is assumed to be only U-234, and U-235/236 is assumed to be only U-235.)

c. The MCL is from the “National Primary Drinking Water Standards” (40 CFR 141) and pertains to total uranium, not each individual uranium isotope.

d. **Bold font** indicates sample concentrations that exceed the MCL (see Footnote c).

MCL = maximum contaminant level

ND = sample result is a nondetection

— = indicates a detection below upper background concentration limits. Soil-moisture upper background values applied to isotopic uranium results in Fiscal Year 2005 are 8.52 pCi/L for U-233/234, 1.34 pCi/L for U-235/236, and 3.86 pCi/L for U-238.

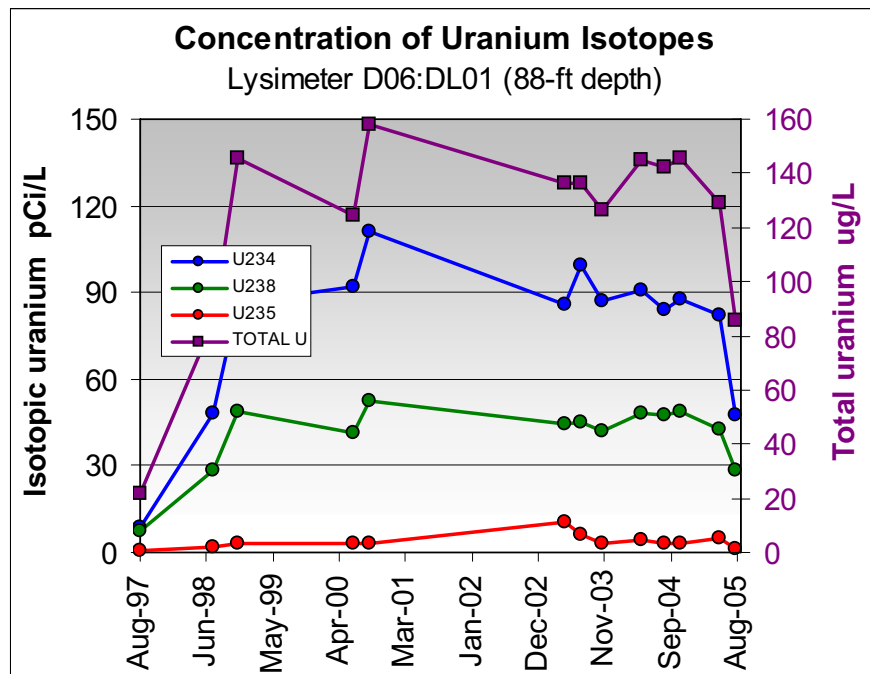


Figure 3-20. Uranium concentrations at Lysimeter D06:DL01.

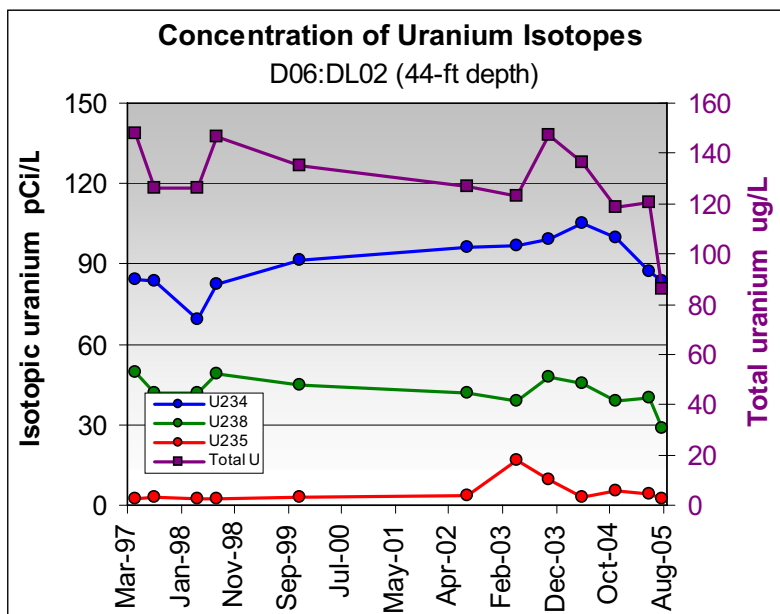


Figure 3-21. Decreasing uranium concentrations at Lysimeter D06:DL02.

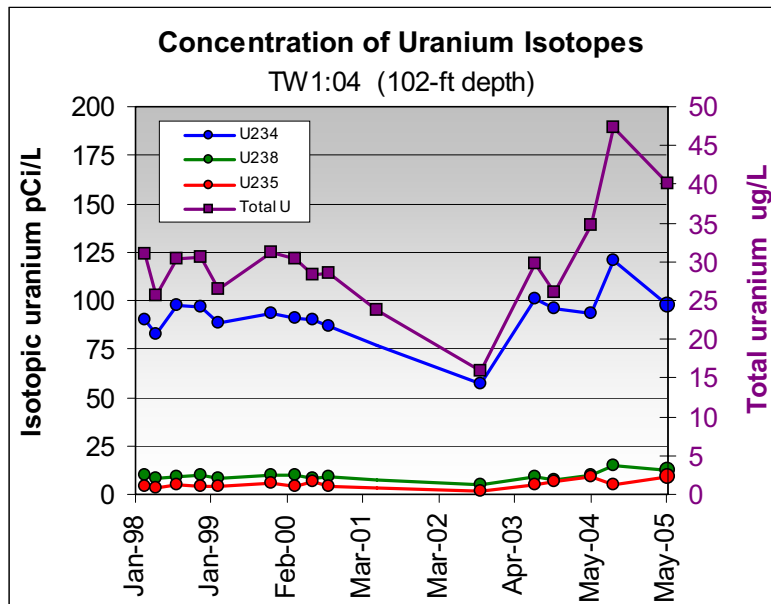


Figure 3-22. Increasing uranium concentrations at Lysimeter TW1:DL04.

Since 1997, 176 analyses of U-233/234, U-235/236, and U-238 were performed on soil-moisture samples collected from 14 shallow lysimeters near RWMC. Concentrations exceeded upper background concentration levels in 37% (65) of the U-233/234 results, 25% (44) of the U-235/236 results, and 40% (71) of the U-238 results. To compare measured concentrations to the MCL, isotopic uranium results were converted from activity (pCi/L) to mass equivalents ($\mu\text{g/L}$) and summed. Since 1997, almost 22% (39) of the intermediate-depth uranium results exceeded the total uranium MCL of 30 $\mu\text{g/L}$. Between 1997 and August 2005, analyses results exceeding the MCL involved five lysimeters, four of which have a history of concentrations above the MCL (i.e., D06:DL01, D06:DL02, I-1S:DL09, and TW1:DL04) (see Tables 3-73, 3-74, and 3-75). Lysimeters with consistently high uranium concentrations are located in monitoring wells near Pad A and Pit 5 (i.e., D06:DL01, D06:DL02, and TW1DL04) and the western part of the SDA (i.e., I-1S:DL09). In Roback et al. (2000) study, using thermal ionization mass spectrometry, samples with uranium concentrations above upper background levels (up to 144 ppb) were found to have natural U-238:U-235 isotope ratios, and no U-236 was detected. Most of these samples were interpreted as natural uranium. Thus, natural background concentrations in these areas are higher than in other locations. Concentrations greater than the MCL remained relatively constant at Location I-1S:DL09, decreased slightly at Locations D06:DL01 and D06:DL02, and increased at Location TW1:DL04. Section 3.12.5 presents concentration ranges, detection rates, and MCL exceedances since 1997.

Table 3-73. Uranium-233/234 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Uranium-233/234 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7 DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																		
	2																		
	3		84																
	4	8.5	84																
1998	1																		
	2																		90
	3		70	2.0															83
	4	48	82	2.4															97
1999	1	86		1.7															97
	2																		90
	3																		
	4																		
2000	1		96																94
	2																		91
	3	92		2.5	18			3.2	1.7	2.8			4.9						93
	4	111			16		10												87
2001	1											1.8							
	2																		
	3			3.8							7.3								5.2
	4																		
2002	1																		
	2																		
	3				17														
	4		96	6.0	15	2.4	2.0					3.1	4.2						

Table 3-73. (continued).

Uranium-233/234 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2003	1			2.1	21			4.4					2.9	3.0					57
	2				17	0.69	0.85					1.1	1.4	1.2					
	3	86	97	2.7	16	1.3	2.7	8.4		5.0		2.7	1.5	4.1					
	4	100		1.5	14		2.9	7.0		2.6		3.2	2.4	3.7					101
2004	1	87	99	2.0	14		3.3	6.8				2.4	1.8						96
	2				9.3			11		5.0		2.6	2.1						84*
	3	91	105		15	2.2	4.3	12		3.8									93
	4	84			17		4.0												121
2005	1	88	100		18			11		4.2				7.0					
	2				16	2.5	4.8	7.2											
	3	82	87	2.4			4.1	8.3		8.5				7.2	12		7.1		98
	4	84	48	1.9		1.5	5.1	6.8					2.4		11			3.1	
Note 1: The highest result is reported for duplicate samples or reanalysis. Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square). For comparison, the MCL = 30 µg/L for total uranium. MCL = maximum contaminant level * = result was initially associated with Lysimeter TW1:DL03; however, investigations in 2004 and 2005 revealed the sample was actually collected from Lysimeter TW1:DL04.																			
	U-233/234 was analyzed, but not detected.																		
x.xx	U-233/234 was detected at or below local soil moisture upper background concentration (8.52 pCi/L).																		
	U-233/234 was detected above local soil-moisture background, but less than the MCL.																		
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																		

Table 3-74. Uranium-235/236 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Uranium-235/236 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7 DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																		
	2																		
	3		2.2																
	4		2.9																
1998	1																		
	2																		4.1
	3		2.4																2.9
	4	1.7	2.5																4.7
1999	1	2.8																	4.3
	2																		4.3
	3																		
	4																		
2000	1		3.2																5.7
	2																		4.1
	3	3.3		1.0	1.4			0.78	0.90				0.65						8.2
	4	2.9																	4.3
2001	1																		
	2																		
	3																		
	4																		
2002	1																		
	2																		
	3																		
	4		3.7		2.6			1.2											

Table 3-74. (continued).

Uranium-235/236 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7 DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2003	1							1.7											1.8
	2																		
	3	10	17					0.71						0.95					
	4	6.0																	4.8
2004	1		9.4																6.3
	2																		4.5*
	3	4.5	2.9																8.8
	4	2.8																	5.1
2005	1	2.8	5.2																
	2																		
	3	4.9	4.4														2.8		9.5
	4		2.2																
Note 1: The highest result is reported for duplicate samples or reanalysis.																			
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																			
* =result was initially associated with Lysimeter TW1:DL03; however, investigations in 2004 and 2005 revealed the sample was actually collected from Lysimeter TW1:DL04.																			
For comparison, the MCL = 30 µg/L for total uranium.																			
MCL = maximum contaminant level																			
	U-235/236 was analyzed, but not detected.																		
x.xx	U-235/236 was detected at or below local soil moisture upper background concentration (1.34 pCi/L).																		
	U-235/236 was detected above local soil-moisture background, but less than the MCL.																		
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																		

Table 3-75. Uranium-238 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997.

Uranium-238 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
1997	1																		
	2																		
	3		49																
	4	7.2	42																
1998	1																		
	2																		9.8
	3		42																8.2
	4	28	49	1.2															9.5
1999	1	49		0.68															9.6
	2																		9.1
	3																		
	4																		
2000	1		47																9.6
	2																		9.6
	3	41		1.6	10		1.5	2.1	1.3	3.1									9.1
	4	53			9.3		4.5												8.9
2001	1											0.87							
	2																		
	3										4.7								2.6
	4																		
2002	1																		
	2																		
	3				9.4			1.7											
	4		42		8.9			3.6				1.1	2.0						

Table 3-75. (continued).

Table 5-137 (continued):

Uranium-238 Radioactive Waste Management Complex Lysimeters (35 to 140 ft)																			
Fiscal Year	Quarter	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	R1935: DL60	1936: DL68	R2004: DL50	R2006: DL46	TW1: DL04
2003	1				9.9	1.4		2.4					1.4	1.3					5.1
	2				8.4	0.60						0.39	0.56	0.44					
	3	44	39		9.9	0.89		4.7				1.0	1.7	1.1					
	4	45			8.3		2.1	4.2						2.5					9.3
2004	1	42	48		8.8		2.2	4.3						1.6					7.8
	2				4.8			4.1		1.7									8.7*
	3	48	45		12		3.1	6.0		3.2									10
	4	47			8.4		3.3												15
2005	1	49	39		12		2.9			3.4									
	2				10		1.8	4.3											
	3	43	40				2.1	5.2		2.6				3.0	11		2.6		12
	4	29	41					4.5							11			3.6	
Note 1: The highest result is reported for duplicate samples or reanalysis.																			
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																			
For comparison, the MCL = 30 µg/L for total uranium.																			
* = result was initially associated with Lysimeter TW1:DL03; however, investigations in 2004 and 2005 revealed the sample was actually collected from Lysimeter TW1:DL04.																			
MCL = maximum contaminant level																			
	U-238 was analyzed, but not detected.																		
x.xx	U-238 was detected at or below local soil-moisture upper background concentration (3.86pCi/L).																		
	U-238 was detected above local soil-moisture background, but less than the MCL.																		
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																		

One previous observation in this depth range involves U-238:U-235 activity ratios at some monitoring locations. Activity ratios for U-238:U-235, which are constant in nature, were interpreted to exhibit subtle changes at monitoring locations D06:DL01 and D06:DL02. The U-238:U-235 activity ratios at the other two lysimeter locations with concentrations above upper background limits (i.e., I-1S:DL09 and TW1:DL04) also were thought to indicate the presence of slightly enriched uranium. Isotopic ratios were used to conclude (erroneously) that enriched uranium with a slight U-235 enrichment was present at these locations. However, revised interpretations of U-238:U-235 ratios (see Section 3.12.1.1) finds no conclusive evidence that enriched uranium is present. Uranium concentrations at locations D06:DL01, D06:DL02, and I-1S:DL09 are interpreted as naturally occurring, while TW1:DL04 shows anthropogenic uranium with slight U-235 enrichment (see Figure 3-22). The interpretation that uranium concentrations up to 144 ppb may be naturally occurring is supported by Roback et al. (2000), which reports that such concentrations may have natural uranium isotopic ratios and have no U-236.

Isotopic ratios at TW1:DL04 clearly indicate uranium at this location is anthropogenic and slightly enriched with U-235. This interpretation is further supported by thermal ionization mass spectrometry analysis of a TW1 sample in 1999 (Roback et al. 2000). As shown in Figure 3-22, the total uranium concentration (and, though less obvious, the U-235 concentration) has gradually increased since the later part of 2002.

Though isotopic ratios around Pad A (i.e., locations D06:DL01 and D06:DL02) and the western end of the SDA (i.e., location I-1S:DL09) are within the range of naturally occurring uranium, other contaminants are detected in these locations. Presence of these other contaminants in combination with higher uranium concentrations could be interpreted as leachate influencing concentrations in these wells. The following points support this interpretation:

- Uranium concentrations are significantly higher at these monitoring locations than all other lysimeters in this depth range
- Pad A contains a substantial portion (approximately 13%) of the total uranium buried in the SDA
- Other constituents often associated with uranium-bearing waste (e.g., from reactor operations) are detected at these locations
- Shallow-depth lysimeters around Pad A (i.e., Lysimeters PA01:L15, PA02:L16, and PA03:L33) exhibit similar uranium coincident with concentrations of other constituents.

3.12.3.3 Lysimeter and Perched Water Samples at Depths Greater Than 140 ft. In FY 2005, 60 U-233/234, U-235/236, and U-238 analyses were performed on soil-moisture samples collected from 23 deep lysimeters and two perched water wells near RWMC. Soil-moisture concentrations in this depth range that exceeded upper background concentration levels were 10% (six) of the U-233/234, 3% (two) of the U-235/236, and 17% (10) of the U-238. To compare measured concentrations to the drinking water MCL, isotopic uranium results were converted from activity (pCi/L) to mass (µg/L) and summed; approximately 7% (four) of the deep-depth uranium results performed in FY 2005 exceeded the total uranium MCL of 30 µg/L. In FY 2005, analyses results exceeding the MCL involved three lysimeters (i.e., IE6:DL34, R1936:DL63, and R1936:DL65), none of which have a long history of elevated concentrations. Table 3-76 presents isotopic uranium analyses results exceeding local soil-moisture upper background concentrations, including the calculated total uranium concentration and MCL exceedances. Section 3.12.5 presents a summary of concentration ranges, detection frequencies, and MCL exceedances in FY 2005, along with a figure showing the sample locations where uranium was detected above the MCL.

Table 3-76. Isotopic uranium concentrations in deep (greater than 140 ft) lysimeters exceeding local soil-moisture background in Fiscal Year 2005.

Lysimeter	Lysimeter Depth (ft)	Sample Date	Sample Result (pCi/L)			Total Uranium ^a	Comparison Concentration
			U-233/234	U-235/236	U-238	Calculated Result (μg/L) ^b	Maximum Contaminant Level ^c (μg/L)
IE6:DL34	215	11/16/04	—	ND	—	2.9 ± 1.2	30
		02/02/05	—	ND	—	3.4 ± 1.4	30
		05/24/05	14.3 ± 1.7	ND	3.6 ± 0.7	11 ± 2	30
		08/09/05	77 ± 6	2.4 ± 0.7	22 ± 2	66 ± 7^d	30
		11/09/05 ^e	136 ± 12 ^c	4.1 ± 1.2 ^c	39 ± 4 ^c	118 ± 13^d	30
R1936:DL63	302	11/17/04	12.8 ± 1.5	ND	12.2 ± 1.5	37 ± 4^d	30
		05/26/05	12.1 ± 1.6	1.9 ± 0.6	12.4 ± 1.6	38 ± 5^d	30
		08/010/05	12.4 ± 1.6	ND	10.9 ± 1.5	33 ± 5^d	30
R1936:DL65	233	11/17/04	18 ± 2	ND	11.5 ± 1.5	35 ± 5^d	30

a. Reported isotopic uranium concentrations (pCi/L) are converted to mass units (μg/L) and summed in order to compare results to the drinking water MCL.

b. Conversion from activity units (pCi/L) to mass units (μg/L) are performed using the following values:

- U-233/234 pCi/L × 1.6023735E-04 = U-234 μg/L
- U-235/236 pCi/L × 4.6240480E-01 = U-235 μg/L
- U-238 pCi/L × 2.9734887E+00 = U-238 μg/L.

(Note: U-233/234 is assumed to be only U-234, and U-235/236 is assumed to be only U-235.)

c. The MCL is from the “National Primary Drinking Water Standards” (40 CFR 141) and pertains to total uranium, not each individual uranium isotope.

d. **Bold font** indicates sample concentrations that exceed the MCL (see Footnote c).

e. Uranium results are for FY 2006 and are included here because they provide critical information regarding the trend.

MCL = maximum contaminant level

ND = sample result is a nondetection.

— = indicates a detection below upper background concentration limits. Soil moisture upper background values applied to isotopic uranium results in Fiscal Year 2005 are 8.52 pCi/L for U-233/234, 1.34 pCi/L for U-235/236, and 3.86 pCi/L for U-238.

Since 1997, 170 analyses of U-233/234, U-235/236, and U-238 were performed on soil-moisture samples collected from 29 lysimeters and five perched water wells near RWMC. About 5% (eight) of the U-233/234, 1% (two) of the U-235/236, and 8% (14) of the U-238 soil-moisture concentrations in this depth range exceeded upper background concentration levels. In comparing measured concentrations to the MCL, isotopic uranium results were converted from activity (pCi/L) to mass equivalents (μg/L) and summed; 2.3% (four) of the uranium results since 1997 exceeded the total uranium MCL of 30 μg/L. Between 1997 and August 2005, analyses results exceeded the MCL in Lysimeters IE6:DL34, R1936:DL63, R1936:DL65, none of which have a history of concentrations above upper background limits. Before these recent exceedances, no uranium concentrations in this depth interval exceeded the total uranium MCL. Tables 3-77, 3-78, and 3-79 show U-233/234, U-235/236, and U-238 detections in deep (i.e., greater than 140 ft) lysimeters and perched water since 1997. Section 3.12.5 summarizes concentration ranges, detection frequencies, and MCL exceedances since 1997.

Table 3-77. Uranium-233/234 detections in deep (greater than 140 ft) lysimeters and perched water since 1997.

Uranium-233/234																																	
Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																																	
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	R2006: DL43	S1898: DL40	USGS-092
1997	1																																
	2																																
	3																																
	4																																
1998	1																																
	2																																
	3																																6.9
	4																																1.9
1999	1																																7.5
	2																																2.5
	3																																
	4																																
2000	1																																3.0
	2		1.3																														6.7
	3																																
	4																																
2001	1																																
	2																																
	3																																
	4																																
2002	1																																
	2																																3.8
	3																																
	4																																
2003	1		2.0																														4.4
	2																																2.9
	3																																3.3
	4																																2.7
2004	1																																2.8
	2			2.1																													2.0
	3			2.3																													3.3
	4			2.8			1.0	5.2																									3.8
2005	1			2.6																													
	2		1.8	2.9																													3.3
	3			1.9				5.4																									2.3
	4			2.7																													4.2
Note 1: The highest result is reported for duplicate samples or reanalysis.																																	
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square). For comparison, the MCL = 30 µg/L for total uranium. MCL = maximum contaminant level																																	
	U-233/234 was analyzed, but not detected.																																
x.xx	U-233/234 was detected at or below local soil moisture upper background concentration (8.52 pCi/L).																																
	U-233/234 was detected above local soil-moisture background, but less than the MCL.																																
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																																

Table 3-79. Uranium-238 detections in deep (greater than 140 ft) lysimeters and perched water since 1997.

Uranium-238 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																																	
Fiscal Year	Quarter	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	R1935: DL52	R1935: DL54	R1935: DL55	R1935: DL56	R1935: DL57	R1935: DL58	R1936: DL62	R1936: DL63	R1936: DL65	R1936: DL67	R2006: DL43	S1898: DL40	USGS- 092
1997	1																																
	2																																
	3																																
	4																																
1998	1																																
	2																																
	3																																3.6
	4																																
1999	1																																4.7
	2																																
	3																																
	4																																
2000	1																																1.3
	2																																3.2
	3																																
	4																																
2001	1																																
	2																																
	3																																
	4																																
2002	1																																
	2																																3.2
	3																																
	4																																
2003	1																																3.7
	2																																2.1
	3																																1.4
	4																																2.6
2004	1																																
	2																																
	3																																
	4																																
2005	1																																
	2																																
	3																																
	4																																
Note 1: The highest result is reported for duplicate samples or reanalysis.																																	
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																																	
For comparison, the MCL = 30 µg/L for total uranium.																																	
MCL = maximum contaminant level																																	
	U-238 was analyzed, but not detected.																																
x.xx	U-238 was detected at or below local soil moisture upper background concentration (3.86 pCi/L).																																
	U-238 was detected above local soil-moisture background, but less than the MCL.																																
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																																

Three samples have been collected from Lysimeter R1936:DL63 and one from Lysimeter R1936:DL65 since monitoring Well R1936 was installed in 2004. Thus, insufficient data are available to properly evaluate uranium results and to assess trends at these locations. A significant increase and concentration trend developed recently at Lysimeter IE6:DL34 (see Figure 3-23). Subtle changes in uranium concentrations began between August 2004 and February 2005, with the most notable changes occurring after February 2005. Besides uranium, VOCs and tritium also were detected above background at this location. Isotopic uranium ratios for Lysimeter IE6:DL34 are at the upper boundary of the background ratio window, suggesting the uranium may possibly have a slight U-235 enrichment (see Figure 3-26). Unvalidated monitoring data from the first quarter 2006 sampling event (received prior to publication of this report) shows that uranium concentrations at Location IE6:DL34 have increased again.

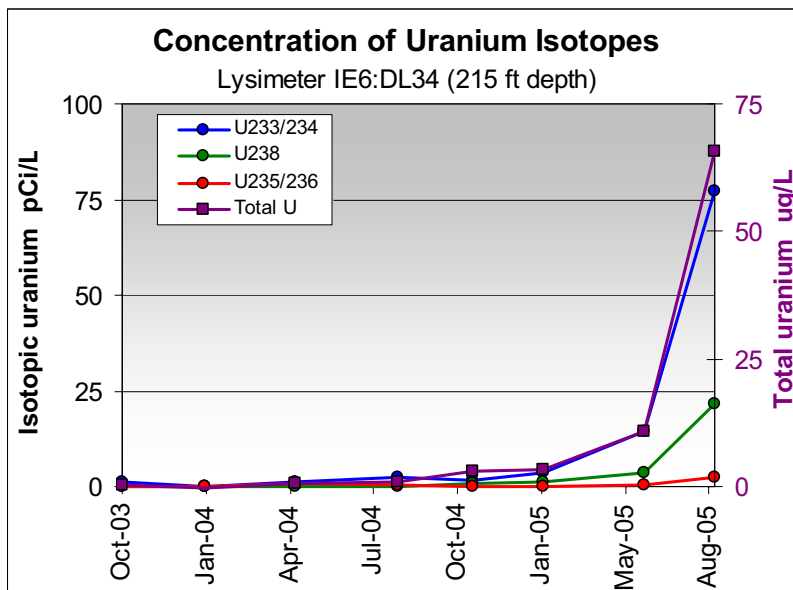


Figure 3-23. Uranium concentration trend at lysimeter IE6:DL34.

Figures 3-21 through 3-23 show uranium concentrations at most deep monitoring locations are near background values. Uranium concentration trends or isotopic ratio trends associated with any of the deep vadose zone monitoring wells are not discernable. All detections in soil moisture at this depth and location are consistent with natural uranium.

3.12.4 Aquifer

From October 2004 through May 2005, 35 U-233/234, U-235/236, and U-238 analyses were performed on aquifer samples collected from 15 monitoring wells near RWMC. All isotopic uranium concentrations were less than established upper tolerance limits and were within concentration ranges typically observed in the aquifer. Also, the total uranium concentration of all samples was less than the drinking water MCL of 30 µg/L.

Since 1998, 386 analyses of U-233/234, and 385 analyses of U-235/236 and U-238 were performed on aquifer samples collected from 16 monitoring wells near RWMC. About 1% (four) of the U-233/234, 2.6% (10) of the U-235, and 0.5% (two) of the U-238 detections exceeded upper background concentration limits (see Tables 3-80, 3-81, and 3-82). However, the total uranium concentration has never exceeded the MCL of 30 µg/L. Section 3.12.5 summarizes concentration ranges, detection rates, and exceedances since 1998.

Table 3-80. Uranium-233/234 detections in aquifer monitoring wells since 1998.

Uranium-233/234 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Fiscal Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11 A31	OW-2	USGS-127
1998	1																
	2																
	3	0.78	1.4	0.49	1.1	1.4	0.73										
	4	1.0	1.7	0.61	1.3	1.5	0.93	1.3	1.4	1.4	1.4						
1999	1	0.91	1.5	0.53	1.2	1.4	0.72	1.3	1.3	1.5	1.5						
	2	0.90	1.4	0.44	1.2	1.3	0.79	1.2	1.4	1.2	1.4						
	3	0.93	1.4	0.42	1.2	1.3	0.66	1.4	1.5	1.4	1.5						
	4	0.87	1.4	0.42	1.2	1.1	0.71	1.3		1.5	1.2						
2000	1	0.87	1.3	1.5	1.2	1.3	0.79	1.2	1.4	1.2	1.4						
	2	0.89		0.40	1.2	1.3	0.57	1.3	1.3	1.3	1.5	1.1	1.4				
	3													1.2			
	4	0.89	1.4	0.42	1.3	1.4	0.63	1.2	1.4	1.3	1.6	1.2	1.3	1.3			0.99
2001	1	1.1	1.3	0.52	1.1	1.3	0.84	1.2		1.2	1.7	0.84	1.3	1.2	0.90	1.8	1.0
	2	0.89	1.6		1.1	1.2		1.1	1.6	1.1	1.3	1.1	1.2	1.2	0.92	1.6	1.1
	3	0.85	1.4	0.56	1.1	1.3		1.1	1.4	1.3	1.3	1.2	1.2	1.2	1.2	1.5	1.0
	4	0.78	1.5	0.55	1.1	1.3		1.2	1.4	3.7	4.3	1.1	1.3	1.1		1.6	1.0
2002	1	0.89	1.4	0.45	1.3	1.3		1.2	1.5	1.3	1.4	1.2	1.3	1.3	0.95	1.5	1.0
	2	0.91	1.5	0.47	1.2	1.3		1.3	1.3	1.2	1.4	1.2	1.2	1.2	0.94	1.6	0.99
	3	0.82	1.4	1.7	1.1	1.4			1.4	1.4	1.6	1.1	1.4	1.3	1.4	0.51	1.0
	4	0.86	1.3	0.45	1.3	1.2		1.3	1.4	1.4	1.5	1.1	1.6	1.3	1.2	1.5	1.1
2003	1	0.83	1.3	0.46	1.2	1.4		1.3	1.5	1.4	1.5	1.2	1.3	1.2	1.2	1.7	1.0
	2	0.86	1.4	0.41	1.2	1.4			1.5	1.4	1.6	1.1	1.3	1.2	1.7	1.8	1.1
	3	0.92	1.4	0.43	1.1	1.3			1.3	1.3	1.3	1.1	1.3	1.1	1.2	1.6	1.1
	4	0.90	1.5	0.40	1.3	1.4		1.2	1.6	1.4	1.5	1.3	1.4	1.2	1.6	2.0	1.1
2004	1	0.77	1.5	0.40	1.2	1.3		1.3	1.4	1.3	1.5	1.1	1.3	1.1	1.5	1.6	1.1
	2	0.86	1.5	0.38	1.1	1.4		1.3	1.5	1.2	1.5	1.1	1.3	1.3	1.6	1.8	1.1
	3	0.92	1.5	0.48	1.2	1.3		1.2	1.5	1.4	1.3	1.2	1.3		1.1	2.1	1.2
2005	1	0.81	1.4	0.42	1.3	1.3		1.2	1.5	1.3	1.3	1.3	1.4	1.1	1.4	1.7	0.97
	2	0.94	1.4	0.51	1.5	1.3		1.4	1.7	1.2	1.3	1.1	1.3	1.2	1.4	1.8	1.1
Note 1: The highest result is reported for duplicate samples or reanalysis.																	
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																	
For comparison, the MCL = 30 µg/L for total uranium.																	
MCL = maximum contaminant level																	
	U-233/234 was analyzed, but not detected.																
x.xx	U-233/234 was detected at or below aquifer background upper tolerance limits (1.92 pCi/L).																
	U-233/234 was detected above aquifer background tolerance limits but less than the MCL.																
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																
	Well is out of service. Well was rendered inoperable after repairs were unsuccessful.																

Table 3-81. Uranium-235/236 detections in aquifer monitoring wells since 1998.

Uranium-235/236 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11 A31	OW-2	USGS- 127
1998	1																
	2																
	3																
	4	0.09		0.04	0.09	0.09		0.08	0.08	0.05							
1999	1																
	2		0.06						0.04	0.04	0.07						
	3	0.05				0.04		0.04	0.04		0.05						
	4		0.04					0.04									
2000	1		0.04		0.03	0.05			0.03		0.03						
	2				0.05			0.06	0.06	0.06	0.05						
	3													0.04			
	4		0.04		0.04				0.03		0.04		0.04				
2001	1	0.04	0.05			0.05	0.03	0.03		0.04	0.06	0.02		0.04	0.05		0.03
	2																
	3		0.04		0.05	0.05		0.03	0.06	0.04	0.05	0.06	0.11	0.04		0.18	
	4	0.04	0.30		0.20			0.08	0.08	0.27		0.06					
2002	1		0.14		0.05	0.04		0.06						0.08		0.08	0.06
	2		0.03		0.06	0.05		0.05	0.05	0.05	0.06	0.08		0.07		0.06	0.04
	3			0.05	0.07							0.05	0.05		0.07		
	4		0.07		0.05				0.08		0.07		0.06	0.07	0.04	0.18	
2003	1		0.07						0.11	0.04		0.04				0.05	0.05
	2		0.05	0.03	0.04	0.05			0.03	0.04		0.04	0.05		0.05	0.14	
	3	0.04	0.11	0.04	0.07	0.09			0.11	0.07	0.06	0.06	0.15	0.10	0.08	0.06	0.05
	4		0.06		0.07				0.12		0.07	0.26	0.09	0.11	0.08	0.06	
2004	1		0.06		0.06			0.10	0.13	0.10	0.08	0.11	0.06	0.08	0.06	0.22	0.09
	2		0.06			0.16		0.09	0.12	0.08	0.09		0.04			0.07	
	3	0.10	0.13		0.06			0.04	0.22	0.14	0.22	0.08	0.14		0.13	0.10	0.08
2005	1			0.03	0.03	0.04					0.06		0.06	0.05	0.02	0.05	
	2		0.08			0.08		0.05	0.09	0.09	0.11	0.06	0.07	0.12			

Note 1: The highest result is reported for duplicate samples or reanalysis.

Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).

For comparison, the MCL = 30 µg/L for total uranium

MCL = maximum contaminant level

U-235/236 was analyzed, but not detected.

x.xx U-235/236 was detected at or below aquifer upper background (0.15 pCi/L).

U-235/236 was detected above aquifer background, but less than the MCL.

U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).

Well is out of service. Well was rendered inoperable after repairs were unsuccessful.

Table 3-82. Uranium-238 detections in aquifer monitoring wells since 1998.

Uranium-238 Radioactive Waste Management Complex Aquifer Monitoring Wells																	
Year	Qtr	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11 A31	OW-2	USGS- 127
1998	1																
	2																
	3	0.35	0.60	0.25	0.54	0.56	0.42										
	4	0.53	0.64	0.33	0.65	0.74	0.46	0.66	0.72	0.69	0.58						
1999	1	0.35	0.66	0.29	0.57	0.58	0.38	0.62	0.49	0.51	0.73						
	2	0.38	0.73	0.23	0.60	0.51	0.35	0.53	0.75	0.54	0.63						
	3	0.43	0.62	0.32	0.58	0.67	0.27	0.55	0.72	0.54	0.71						
	4	0.34	0.65	0.28	0.53	0.52	0.32	0.52		0.55	0.65						
2000	1	0.40	0.65	0.67	0.58	0.69	0.35	0.50	0.64	0.48	0.60						
	2	0.46	0.68	0.22	0.56	0.58	0.28	0.57	0.61	0.55	0.62	0.57	0.66				
	3													0.63			
	4	0.43	0.72	0.23	0.52	0.68	0.33	0.47	0.68	0.61	0.67	0.55	0.60	0.58			0.49
2001	1	0.53	0.60	0.25	0.45	0.65	0.37	0.44		0.51	0.71	0.39	0.59	0.60	0.41	0.88	0.57
	2	0.41	0.77	0.25	0.45	0.45		0.49	0.58	0.54	0.58	0.51	0.63	0.63	0.48	0.85	0.64
	3	0.41	0.65	0.30	0.58	0.62		0.42	0.67	0.49	0.60	0.56	0.53	0.51	0.54	0.64	0.50
	4	0.38	0.46	0.32	0.57	0.60		0.44	0.64	1.71	2.12	0.50	0.64	0.48		0.89	0.47
2002	1	0.42	0.59	0.28	0.62	0.56		0.47	0.60	0.54	0.65	0.54	0.62	0.70	0.41	0.75	0.44
	2	0.36	0.59	0.28	0.54	0.59		0.54	0.60	0.54	0.60	0.51	0.67	0.51	0.44	0.75	0.50
	3	0.40	0.57	0.78	0.44	0.67			0.54	0.54	0.54	0.58	0.65	0.60	0.64	0.18	0.59
	4	0.42	0.57	0.23	0.54	0.54		0.61	0.62	0.63	0.71	0.49	0.89	0.63	0.53	0.73	0.58
2003	1	0.43	0.58	0.20	0.62	0.52		0.47	0.67	0.60	0.65	0.58	0.59	0.59	0.60	0.86	0.50
	2	0.42	0.66	0.27	0.54	0.65			0.73	0.58	0.68	0.57	0.65	0.51	0.81	0.89	0.52
	3	0.39	0.62	0.22	0.56	0.56			0.57	0.52	0.66	0.55	0.56	0.51	0.53	0.76	0.51
	4	0.38	0.64	0.28	0.61	0.64		0.43	0.61	0.62	0.67	0.66	0.58	0.53	0.90	0.85	0.51
2004	1	0.34	0.63	0.20	0.60	0.66		0.53	0.64	0.56	0.63	0.54	0.58	0.54	0.65	0.85	0.49
	2	0.38	0.63	0.20	0.46	0.68		0.50	0.71	0.68	0.59	0.59	0.65	0.54	0.78	0.90	0.49
	3	0.35	0.53	0.17	0.56	0.59		0.55	0.58	0.60	0.57	0.49	0.63		0.57	0.84	0.44
2005	1	0.38	0.57	0.20	0.65	0.70		0.44	0.73	0.61	0.82	0.66	0.60	0.61	0.62	0.88	0.54
	2	0.46	0.54	0.24	0.70	0.69		0.56	0.65	0.66	0.71	0.55	0.71	0.56	0.60	0.89	0.52
Note 1: The highest result is reported for duplicate samples or reanalysis.																	
Note 2: For comparison to the total uranium MCL, measured U-233/234 activities are converted to mass equivalents and combined with measured U-235/236 and U-238 mass equivalents. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL (pink square).																	
For comparison, the MCL = 30 µg/L for total uranium.																	
MCL = maximum contaminant level																	
	U-238 was analyzed, but not detected.																
x.xx	U-238 was detected at or below aquifer upper background tolerance limits (0.9 pCi/L).																
	U-238 was detected above aquifer background, but less than the MCL.																
	U-233/234 contributed to a detection greater than the MCL for total uranium (see Note 2).																
	Well is out of service. Well was rendered inoperable after repairs were unsuccessful.																

Historical observations about uranium in the aquifer involve (1) increasing concentrations of U-235/236 at Wells M12S and M13S and (2) changes and trends in U-238:U-235 activity ratios (see Figure 3-24). These changes and trends were initially attributed to anthropogenic uranium from upgradient sources (Koeppen et al. 2005) because low concentrations of anthropogenic uranium were detected in aquifer monitoring wells downgradient of INTEC (Roback et al. 2001). Additional U-235/236 data have been acquired since FY 2004, and as shown in Figure 3-24, U-235/236 concentrations have decreased and are more typical of aquifer background concentrations. The apparent trend may have been an artifact of the relatively high uncertainties associated with U-235/236 measurements. Based on current interpretations of U-238:U-235 and U-234:U-238 ratios (see Section 3.12.1.1), concentrations at Well M12S are characteristic of naturally occurring uranium (see Figure 3-25). Correlation between activity ratios in Figure 3-25 shows that U-234:U-238 uranium ratios at Well M12S are characteristic of naturally occurring uranium. However, decreased U-238:U-235 ratios should show increased U-234:U-238, even for low-enriched uranium (graphed as artificial data point). Highly enriched uranium would show an even greater increase in the U-234:U-238 ratio for a small decrease in the U-238:U-235 ratio.

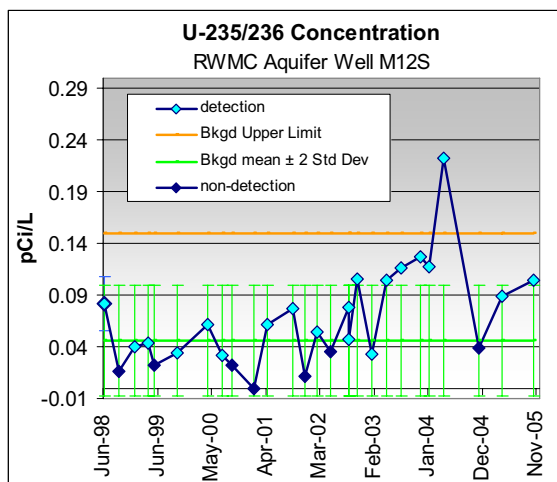


Figure 3-24. Concentration history of U-235/236 at aquifer Well M12S showing data from June 1998.

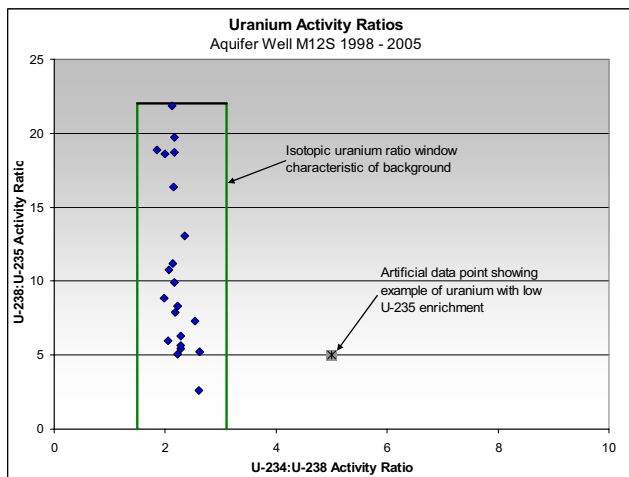


Figure 3-25. Correlation between U-234:U-238 and U-238:U-235 activity ratios showing uranium detected at Well M12S is characteristic of naturally occurring uranium.

3.12.5 Summary of Uranium

Concentrations in all but one location in the vadose zone and aquifer in FY 2005 are consistent with naturally occurring uranium, though numerous vadose zone soil-moisture samples significantly exceed local soil-moisture background levels. The one exception, TW1:DL04 in Pit 5 near Pad A, exhibits concentrations that are indicative of anthropogenic uranium (see Figure 3-26). Uranium at location TW1:DL04 was identified in 2000 as being anthropogenic with a slight U-235 enrichment (Roback et al. 2000), and subsequent monitoring data clearly indicate anthropogenic uranium at this location. Summaries of concentration ranges, detection frequencies, and MCL exceedances for U-233/234, U-235/236, and U-238 are presented in Tables 3-83, 3-84, and 3-85, respectively. In addition, Figure 3-27 shows the monitoring locations where uranium was detected above the MCL in FY 2005.

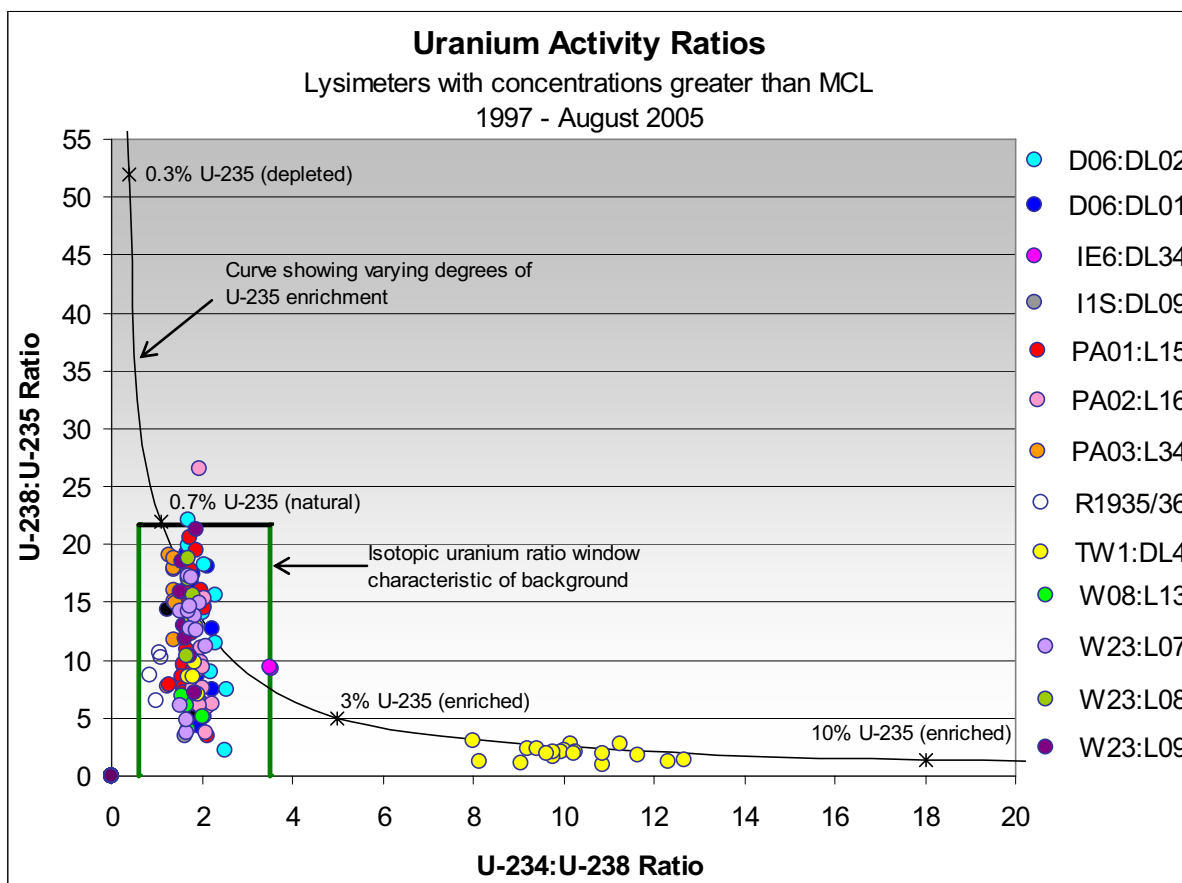


Figure 3-26. Isotopic activity ratios for lysimeters with uranium concentrations exceeding the maximum contaminant level in Fiscal Year 2005.

Table 3-83. Concentration ranges and detection frequencies of uranium-233/234 greater than background levels in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	54.5	18/33	13 ^d	98-5, PA01, PA02, PA03, W06, W08, W23	10.2 ± 1.4	32 ± 3	57 ± 5	
Vadose zone (35 to 140 ft)								
Soil moisture	30.8	12/39	11 ^d	D06, I1S, R1935, TW1	10.5 ± 1.4	54 ± 4	100 ± 8	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	8.3	3/36	2 ^d	IE6, R1936	12.8 ± 1.5	35 ± 3	77 ± 6	
Vadose zone (>250 ft)								
Soil moisture	12.5	3/24	2 ^d	R1936	8.8 ± 1.6	11.1 ± 1.6	12.4 ± 1.6	
Aquifer	0.0	0/35	0	None	NA	NA	NA	

a. Ratio = number of detections exceeding the upper background concentration values/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., MCLs).

c. The following U-234 background concentrations were applied to the various sample media (see Table 2-2):

- 1.92 pCi/L was applied to aquifer and perched water samples
- 8.52 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass units (µg/L) and summed to compare results to the drinking water MCL.

MCL = maximum contaminant level

Table 3-84. Concentration ranges and detection frequencies of uranium-235/236 greater than background levels in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	24.2	8/33	7 ^d	PA01, PA02, PA03, W06, W08, W23	1.4 ± 0.5	3.0 ± 0.7	5.0 ± 0.7	
Vadose zone (35 to 140 ft)								
Soil moisture	17.9	7/39	2 ^d	D06, I1S, TW1	2.2 ± 0.7	4.6 ± 0.9	9.5 ± 1.4	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	2.8	1/36	1 ^d	IE6	NA	NA	2.4 ± 0.7	
Vadose zone (>250 ft)								
Soil moisture	4.2	1/24	1 ^d	R1936	NA	NA	1.9 ± 0.6	
Aquifer	0.0	0/35	0	None	NA	NA	NA	

a. Ratio = number of detections exceeding the upper background concentration values/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., risk-based concentrations and MCLs).

c. The following U-235 background concentrations were applied to the various sample media (see Table 2-2):

- 1.34 pCi/L was applied to aquifer and perched water samples
- 0.15 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass units (µg/L) and summed to compare results to the drinking water MCL.

MCL = maximum contaminant level

Table 3-85. Concentration ranges and detection frequencies of uranium-238 greater than background in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	60.6	20/33	13 ^d	98-5, PA01, PA02, PA03, W06, W08, W23	4.3 ± 0.9	19 ± 2	39 ± 3	
Vadose zone (35 to 140 ft)								
Soil moisture	35.9	14/39	11 ^d	D06, I1S, R1935, TW1	4.3 ± 0.8	22 ± 2	49 ± 4	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	11.1	4/36	2 ^d	IE6, R1936	6.7 ± 1.2	11.9 ± 1.5	22 ± 2	
Vadose zone (>250 ft)								
Soil moisture	25.0	6/24	2 ^d	R1936	4.1 ± 0.8	8.3 ± 1.3	12.4 ± 1.6	
Aquifer	0.0	9/35	0	None	NA	NA	NA	

a. Ratio = number of detections exceeding the upper background concentration values/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., risk-based concentrations and MCLs).

c. The following U-238 background concentrations were applied to the various sample media (see Table 2-2):

- 0.90 pCi/L was applied to aquifer and perched water samples
- 3.68 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass units (µg/L) and summed to compare results to the drinking water MCL.

MCL = maximum contaminant level

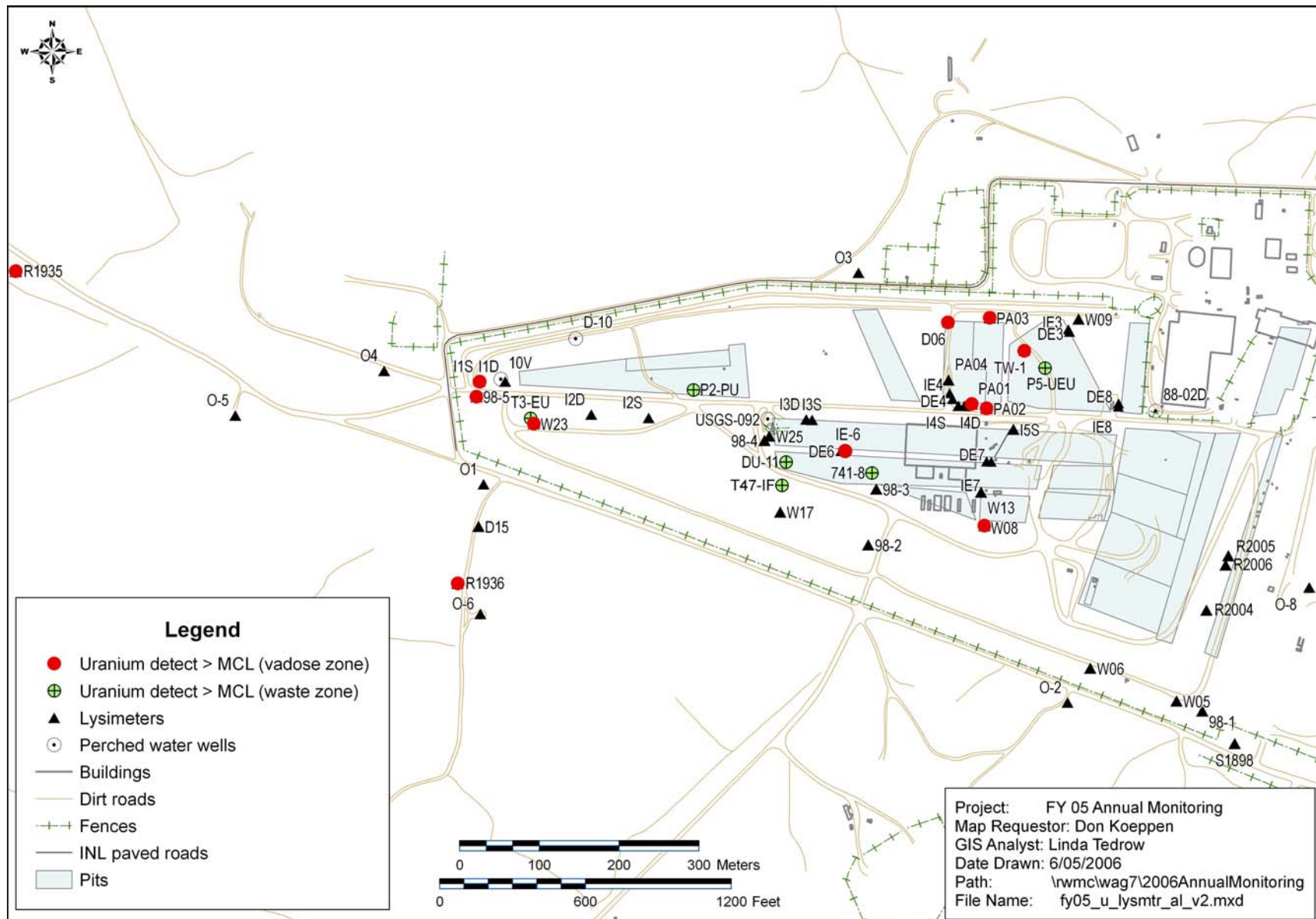


Figure 3-27. Locations of Fiscal Year 2005 uranium (total) detections at concentrations greater than the maximum contaminant level.

Concentrations exceeding local background levels are most prevalent in shallow and intermediate depths of the vadose zone near three specific areas in the SDA—around Pad A and Pit 5, the western end of the SDA, and the Acid Pit. Though levels of uranium at these locations are within the range of naturally occurring uranium, other contaminants also are detected in these same locations, indicating some migration may be influencing sample results. Figure 3-26 shows the correlation between U-234:U-238 and U-238:U-235 ratios of all lysimeters in the SDA with U-234, U-235, and U-238 concentrations above upper background limits or the MCL since 1997. Historically, three atypical concentrations have been detected: two occurring at location PA02 in 1998 and 1999 and one occurring at location W23:L09 in 1998. Subsequent sample results at these two locations exhibited results characteristic of natural uranium. Tables 3-86, 3-87, and 3-88 present concentration ranges, detection rates, and exceedances since monitoring began.

Concentrations of uranium detected in aquifer monitoring wells are consistent with natural background values and have never approached or exceeded the MCL for total uranium. The number of detections of U-233/234 and U-238 exceeding the upper background comparison concentrations are consistent with expected rates (i.e., less than or equal to 1%). The detection rate for U-235/236, which is slightly higher than those for U-233/234 and U-238, is attributed to (1) relatively high measurement uncertainties associated with low-level U-235/236 analyses and (2) a low background comparison concentration at RWMC (ranges at other aquifer monitoring locations around the INL are typically a factor of two higher than at RWMC).

Table 3-86. Concentration ranges and detection frequencies of uranium-233/234 greater than background levels for sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	65.6	139/212	103 ^d	98-5, PA01, PA02, PA03, W06, W08, W23	9 ± 2	35 ± 3	125 ± 10	
Vadose zone (35 to 140 ft)								
Soil moisture	36.9	65/176	39 ^d	D06, I1S, R1935, TW1	8.6 ± 1.2	64 ± 6	121 ± 10	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	3.8	5/133	2 ^d	IE6, R1936	10.1 ± 1.6	25 ± 3	77 ± 6	
Vadose zone (>250 ft)								
Soil moisture	8.1	3/37	2 ^d	R1936	8.8 ± 1.6	11.1 ± 1.6	12.4 ± 1.6	
Aquifer	1.0	4/386	0	None	2.01 ± 0.18	3.0 ± 0.3	4.3 ± 0.4	

a. Ratio = number of detections greater than upper background levels/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., risk-based concentrations and MCLs).

c. The following U-234 upper background concentration levels were applied to the various sample media (see Table 2-2):

- 1.44 pCi/g was applied to surface soil, vegetation, and core samples
- 1.92 pCi/L was applied to run-off water and aquifer samples
- 8.52 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass equivalents and combined. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL.

MCL = maximum contaminant level

Table 3-87. Concentration ranges and detection frequencies of uranium-235/236 greater than background levels for sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	31.6	67/212	65 ^d	PA01, PA02, PA03, W06, W08, W23	1.37 ± 0.19	2.8 ± 0.6	10.2 ± 1.3	
Vadose zone (35 to 140 ft)								
Soil moisture	25.0	44/176	27 ^d	D06, I1S, TW1	1.4 ± 0.3	4.6 ± 0.8	17.0 ± 1.5	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	0.8	1/133	1 ^d	IE6	NA	NA	2.4 ± 0.7	
Vadose zone (>250 ft)								
Soil moisture	2.7	1/37	1 ^d	R1936	NA	NA	1.9 ± 0.6	
Aquifer	2.6	10/385	0	None	0.16 ± 0.02	0.22 ± 0.04	0.30 ± 0.05	

a. Ratio = number of detections greater than upper background levels/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., risk-based concentrations and MCLs).

c. The following U-235 upper background concentration levels were applied to the various sample media (see Table 2-2):

- 0.103 pCi/g was applied to surface soil, vegetation, and core samples
- 0.61 pCi/L was applied to run-off water and aquifer samples
- 0.15 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass equivalents and combined. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL.

MCL = maximum contaminant level

Table 3-88. Concentration ranges and detection frequencies of uranium-238 greater than background levels for sampled media since 1997.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (pCi/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	70.3	149/212	104 ^d	98-5, PA01, PA02, PA03, W06, W08, W23	3.9 ± 0.7	19.7 ± 2.1	54 ± 5
Vadose zone (35 to 140 ft)							
Soil moisture	40.3	71/176	39 ^d	D06, I1S, R1935, TW1	4.2 ± 0.8	21 ± 2	53 ± 5
Vadose zone (140 to 250 ft)							
Soil moisture and perched water	6.0	8/133	2 ^d	IE6, R1936	4.3 ± 1.2	9.0 ± 1.3	22 ± 2
Vadose zone (>250 ft)							
Soil moisture	16.2	6/37	2 ^d	R1936	4.1 ± 0.8	8.3 ± 1.3	12.4 ± 1.6
Aquifer	0.5	2/385	0	None	1.71 ± 0.16	1.92 ± 0.18	2.1 ± 0.2

a. Ratio = number of detections greater than upper background levels/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., risk-based concentrations and MCLs).

c. The following U-238 upper background concentration levels were applied to the various sample media (see Table 2-2):

- 1.40 pCi/g was applied to surface soil, vegetation, and core samples
- 0.90 pCi/L was applied to run-off water and aquifer samples
- 3.68 pCi/L was applied to soil-moisture samples.

d. The value shown is the number of times the isotope contributed to a detection that exceeded the MCL of 30 µg/L for total uranium. Measured U-233/234, U-235/236, and U-238 activities are converted to mass equivalents and combined. If the sum of measured uranium isotopes exceeds the total uranium MCL, each individual isotope is shown as exceeding the MCL.

MCL = maximum contaminant level

3.13 Inorganic Contaminants

Inorganic compounds are broadly categorized as (1) those elements that do not contain carbon; (2) are primarily composed of minerals, metals, and nonmetals; and (3) can be classified as anions and metals. Many anions and metals are constituents commonly found in the environment, but also are contained in many waste processes (e.g., weapons manufacturing, nuclear operations, and agriculture). Other than nitrate, most anions and metals are not contaminants of potential concern and have little or no associated risk; however, some behave as tracers (e.g., chloride and sulfate) and provide useful information about water and transport in the vadose zone. Soil-moisture and aquifer samples collected at RWMC are analyzed for 29 inorganic constituents (anions and metals) specified in field sampling plans for lysimeter, perched water, and aquifer monitoring for OU 7-13/14.

3.13.1 Nitrate

Nitrate is an inorganic anion generally associated with nitrate-containing salt or fertilizer or the aerobic decomposition of organic matter. Nitrate is an anion and is, therefore, readily transported through the vadose zone with infiltrating water. Excess nitrate in groundwater is most commonly associated with large-scale farming operations or feedlots (e.g., from the addition of nitrogen-containing fertilizers or from manure in stockpiles or lagoons). Most nitrate in waste at the SDA originates from nitrate salt produced by weapons manufacturing processes.

Nitrogen is a redox element, and its chemical form in the environment is dependent on the presence or absence of electrons. In reducing environments (e.g., swamps), reduced forms of nitrogen like ammonia are most common. In oxidizing environments, nitrate prevails. Nitrate is the predominant species in RWMC soil, soil-moisture, and aquifer samples.

3.13.1.1 Buried Waste Inventory. About $4.56\text{E}+08$ g of nitrate was buried in the SDA. Most of the nitrate-bearing waste originates from Rocky Flats Plant evaporator salts (Holdren et al. 2006).

3.13.1.2 Vadose Zone

3.13.1.2.1 Lysimeter Samples at Depths from 0 to 35 ft—In FY 2005, 27 nitrate (as nitrogen) analyses were performed on soil-moisture samples collected from 14 shallow vadose zone lysimeters. Of these, 11 samples exceeded the nitrate local soil moisture upper background concentration of 11.4 mg/L and the MCL of 10 mg/L (see Table 3-89) used for comparison.

Concentrations at locations exceeding MCLs in FY 2005 were typical of historical concentrations, except at locations W08:L13 and W25:L28. The concentration trend at location W25:L28 seems to have leveled off, while the concentration at location W08:L13 showed an unexpected increase (see Figure 3-28). Section 3.13.1.4 presents these data, including concentration ranges, detection rates, and exceedances.

Table 3-89. Nitrate (as nitrogen) concentrations detected above background in the shallow-depth (0 to 35 ft) lysimeter in Fiscal Year 2005.

Analyte	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (mg/L)	Comparison Concentrations
					Maximum Contaminant Level ^a (mg/L)
Nitrate-N	11/14/04	PA02:L16	8.7	32.5_R ^{b,c}	10
	02/02/05			35.3^b	
	05/25/05			31.6_R ^{b,c}	
	05/25/05	W08:L12	22.1	26.8_R ^{b,c}	
	05/25/05	W08:L13	11.3	37.7_R ^{b,c}	
	08/08/05			55.6^b	
	05/24/05	W23:L09	7.7	13.7_R ^{b,c}	
	08/09/05			13.5^b	
	05/24/05	W25:L28	15.5	35.4_R ^{b,c}	
	08/09/05			34.7^b	

a. The MCL is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

b. **Bold font** indicates concentration is greater than the MCL.

c. Initial analysis met holding-time requirements; however, nitrate concentrations were sufficient to require dilution, and the second analysis missed the holding time. Therefore, these data are flagged with “R” qualifiers. These results are commensurate with historical data and considered usable, but only as estimated quantities.

MCL = maximum contaminant level

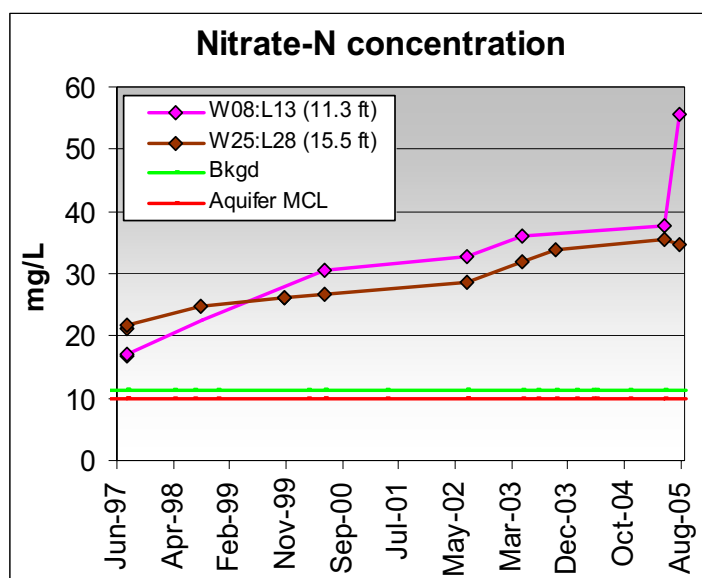


Figure 3-28. Monitoring locations with nitrate (as nitrogen) concentration changes in Fiscal Year 2005.

Since 1997, 153 nitrate (as nitrogen) analyses have been performed on soil-moisture samples collected from 21 shallow lysimeters in and around RWMC. About 44% (67) of the soil-moisture concentrations in the 0 to 35-ft depth range exceeded the upper background concentration level of 11.4 mg/L and consequently exceeded the MCL of 10 mg/L. Analyses results exceeding the MCL between 1997 and August 2005 ranged from 12.9 to 102 mg/L and involved 13 lysimeters, seven of which have a long history of concentrations above the MCL (i.e., PA02:L16, W08:L12, W08:L13, W08:L14, W23:L09, W25:L28, and 98-4). These seven lysimeters are located in four distinct areas in the SDA: Pad A (PA02), western end of the SDA (W23), western end of Pit 4 (98-4 and W25), and the Acid Pit (W08). Section 3.13.1.4 summarizes concentration ranges, detection rates, and exceedances in all monitoring depth intervals since 1997.

Historical concentrations of all lysimeters in the shallow interval of the vadose zone since 1997 show wide variations ranging from 0.12 to 102 mg/L. Background levels of nitrate (as nitrogen) in the vadose zone outside the SDA typically range from 0.1 to 11.4 mg/L, with a mean concentration around 2 mg/L. The highest and most consistently detected nitrate (as nitrogen) concentrations were measured in Well PA02, which is next to Pad A where nitrate-laden waste is buried; in Well W08 near the Acid Pit; and in Well W23 on the western end of the SDA. Concentrations measured at Wells 98-4 and W25, at the western end of Pit 4, are slightly lower than the other locations, but also consistently exceed the MCL. Concentration trends are not evident at these two locations.

A significant concentration trend developed at Well PA02 between May 2001 and January 2004, when it reached a peak concentration of 100 mg/L (see Figure 3-29). However, in November 2004, the concentration decreased significantly to 33 mg/L, hovered around that concentration until August 2005, when it decreased to 9.7 mg/L, a concentration below background and the MCL (see Figure 3-28). No change in nitrate (as nitrogen) concentrations was notable at adjacent Well PA01 during this time; however, at location I4S, which is about 27.4 m (90 ft) beneath PA02, nitrate was detected above background (see Figure 3-28) in July 2002 and has remained above the MCL since that time. The cause of the concentration increase and decrease between 2001 and 2004 has yet to be explained, and whether concentrations at the deeper location are indicative of migration has yet to be determined. Because monitoring for nitrate (as nitrogen) at location I4S did not begin until July 2002, it is difficult to ascertain whether nitrate levels at the 30-m (97-ft) depth were the same prior to 2002.

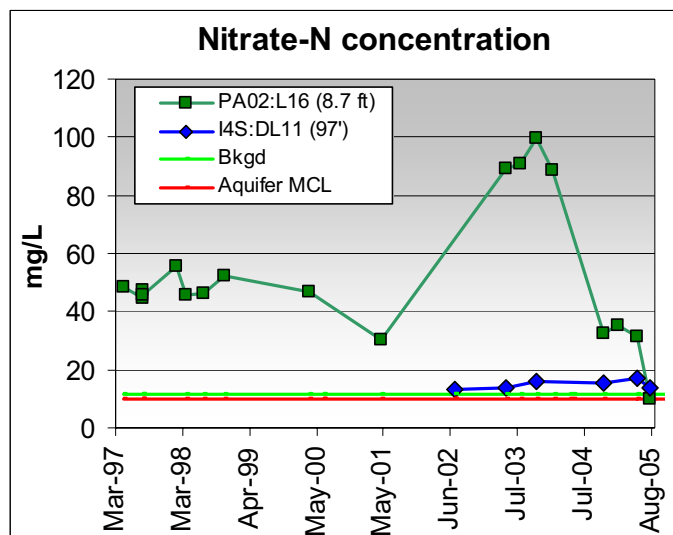


Figure 3-29. Nitrate (as nitrogen) concentration history at Lysimeter Wells PA02 and I4S from 1997 through August 2005.

3.13.1.2.2 Lysimeter Samples at Depths from 35 to 140 ft—In FY 2005, 29 nitrate (as nitrogen) analyses were performed on soil-moisture samples collected from 14 lysimeters. Of these, 10 sample concentrations exceeded the local soil-moisture upper background of 11.4 mg/L and the MCL of 10 mg/L (see Table 3-90) used for comparison.

Table 3-90. Nitrate (as nitrogen) concentrations detected above background in the shallow-depth (0 to 35 ft) lysimeters in Fiscal Year 2005.

Analyte	Sample Date	Lysimeter	Lysimeter Depth (ft)	Sample Result (mg/L)	Comparison Concentrations
					Maximum Contaminant Level ^a (mg/L)
Nitrate-N	11/15/04	D06:DL02	44	13.1_R ^{b,c}	
	05/24/05			14.3^b	
	11/15/04	I-2S:DL11	92	97.9_R ^{b,c}	
	02/07/05			97.2^b	
	05/24/05			116_R ^{b,c}	
	08/09/05	I-4S:DL15	97	93.6^b	
	11/15/04			15.2_R ^{b,c}	
	05/25/05			17.1_R ^{b,c}	
	08/08/05			13.8^b	
	05/24/05	TW1:DL04	101.7	16.8_R ^{b,c}	

a. The MCL is from the “National Primary Drinking Water Standards” (40 CFR 141) and the Implementation Guidance for Radionuclides (EPA 2002).

b. **Bold font** indicates concentration is greater than MCL.

c. Initial analysis met holding-time requirements; however, nitrate concentrations were sufficient to require dilution, and the second analysis missed the holding time. Therefore, these data are flagged with “R” qualifiers. These results are commensurate with historical data and considered usable, but only as estimated quantities.

MCL = maximum contaminant level

In FY 2005, concentrations at locations exceeding MCLs were typical of historical concentrations and exhibited no apparent trends. Most locations with concentrations above background only slightly exceed the upper background level, except for Lysimeter I-2S:DL11, which has the highest concentration in this depth range, significantly exceeding the MCL. The concentration has hovered around 100 mg/L for the past 3 years; however, it began as a trend in 2001 (see Figure 3-30). Section 3.13.1.4 presents these data, including concentration ranges, detection rates, and exceedances.

Since 1997, 100 nitrate (as nitrogen) analyses have been performed on soil-moisture samples collected from 16 intermediate-depth lysimeters in and around the RWMC. About 31% (31) of the soil-moisture concentrations in the 35 to 140-ft depth range exceeded the upper background concentration level of 11.4 mg/L, and consequently exceeded the MCL of 10 mg/L. Analyses results exceeding the MCL between 1997 and August 2005 range from 12 to 116 mg/L and involved six lysimeters, four of which have a long history of concentrations above the MCL (i.e., D06:DL02, I-2S:DL11, I-4S:DL15, and TW1:DL04). These four lysimeters are located in three distinct areas in the SDA: Pad A (i.e., D06 and I-4S), Pit 5 (i.e., TW1), and the western end of the SDA (i.e., I-2S). Section 3.13.1.4 summarizes concentration ranges, detection rates, and MCL exceedances in all monitoring depth intervals since 1997.

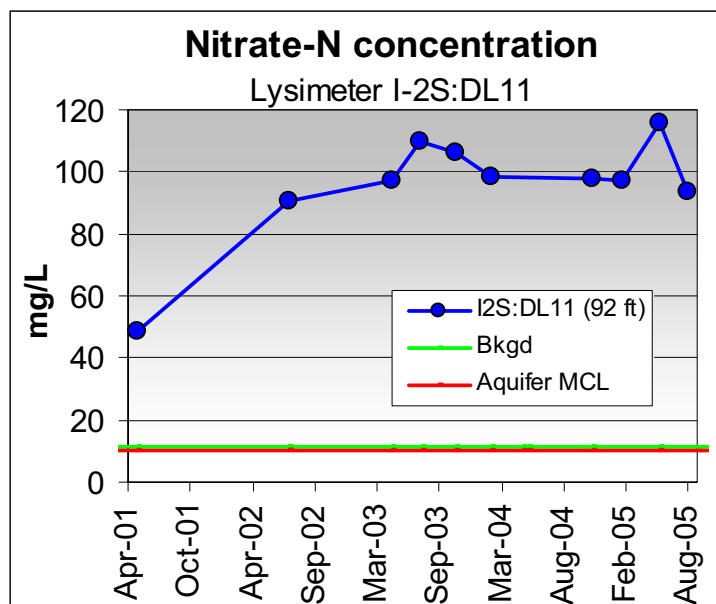


Figure 3-30. Nitrate (as nitrogen) concentration history at Lysimeter I-2S:DL11 from April 2001 through August 2005.

Similar to the shallow vadose zone, historical nitrate (as nitrogen) concentrations in the intermediate vadose zone also show wide variations, ranging from 0.1 to 116 mg/L in Well I2S. As mentioned in the previous paragraph, Well I2S has the highest nitrate (as nitrogen) concentration observed in the 35 to 140-ft depth interval (see Figure 3-30). Wells monitored around Pad A (i.e., D06, TW1, and I4S) generally have nitrate (as nitrogen) concentrations, ranging from 12 to 32 mg/L. Nitrate (as nitrogen) concentrations in Well I4S may indicate nitrate contamination has migrated to about 30.5 m (100 ft) deep around Pad A (see discussion in the previous section). Nitrate (as nitrogen) concentrations at Lysimeters D06:DL01 and D06:DL02 have gradually decreased over time, suggesting migration; however, the concentration at the deeper depth is more indicative of background levels (see Figure 3-31).

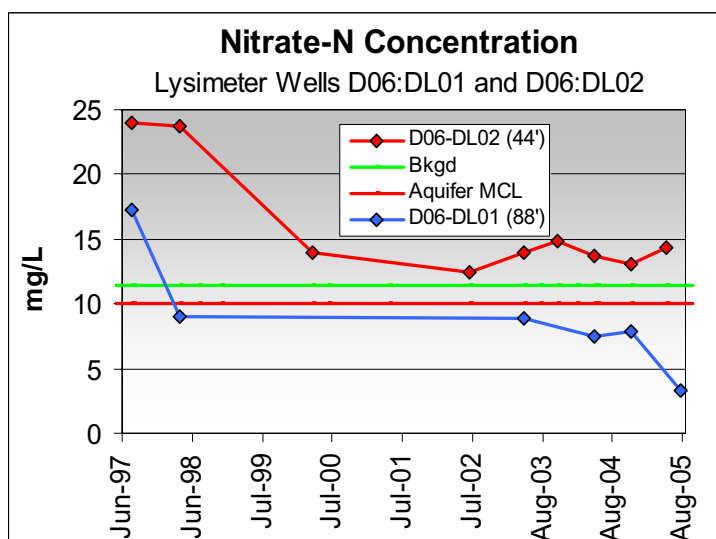


Figure 3-31. Lysimeters beneath Pad A at 44 and 88 ft exhibiting decreasing nitrate (as nitrogen) trends.

3.13.1.2.3 Lysimeter Samples at Depths Greater Than 140 ft—In FY 2005, 35 nitrate (as nitrogen) analyses were performed on samples collected from 18 lysimeters and two perched water wells, with no concentrations exceeding perched water or soil-moisture upper background levels or the MCL. Nitrate (as nitrogen) concentrations in this depth interval range from 0.10 to 9.2 mg/L. Concentrations in the deep vadose zone soil moisture and perched water are near background levels and exhibit much less variation than do nitrate (as nitrogen) concentrations in the shallow and intermediate vadose zone.

Since 1997, 93 nitrate (as nitrogen) analyses have been performed on soil-moisture samples collected from 31 deep lysimeters (greater than 140 ft) near RWMC. About 4% (three) of the soil-moisture and perched water concentrations in this depth range exceeded the upper background concentration level of 11.4 mg/L, and consequently exceeded the MCL of 10 mg/L. Results exceeding the MCL between 1997 and August 2005 involved Lysimeter I-2D:DL10 (July 2002) and perched water Well USGS-92 (May and July 2003). Subsequent samples from these locations have been below upper background levels and the MCL.

3.13.1.3 Aquifer. In FY 2005, 34 nitrate (as nitrogen) analyses were performed on samples collected from 15 RWMC monitoring wells around the RWMC, and none of the measured concentrations exceeded the maximum background concentration of 5 mg/L or the MCL of 10 mg/L. Nitrate (as nitrogen) concentrations in RWMC monitoring wells in FY 2005 ranged from 0.11 to 2.3 mg/L, which are typical of levels normally found in the Snake River Plain Aquifer.

Since 1997, 93 nitrate (as nitrogen) analyses have been performed on soil-moisture samples collected from 31 deep lysimeters (greater than 140 ft) near RWMC. All INL RWMC wells sampled from 1997 to May 2005 showed nitrate (as nitrogen) concentrations below the MCLs; these levels were characteristic of levels normally detected in the Snake River Plain Aquifer. The reported levels of nitrate (as nitrogen) typically found in the Snake River Plain Aquifer are 1 to 2 mg/L, with concentrations that range from 0.4 to 5 mg/L (Knobel, Orr, and Cecil 1992). The range of concentrations associated with RWMC aquifer monitoring wells, from 1997 to May 2005, varied from a minimum of 0.28 mg/L to a maximum of 3.4 mg/L, with a mean concentration of 0.85 mg/L. Concentrations in Well M6S are slightly higher than all other RWMC monitoring wells around RWMC, with a mean concentration of 2.0 mg/L. The concentration at Well M6S exhibited a short-lived concentration trend between October 1999 and October 2000, when it reached a peak concentration of 3 mg/L, then leveled off around 2 mg/L in November 2001 and has remained at this concentration (see Figure 3-32). The reason for nitrate (as nitrogen) levels at Well M6S remaining higher than all other wells near RWMC has yet to be determined. Section 3.13.1.4 summarizes these data, including concentration ranges, detection rates, and MCL exceedances since 1997.

3.13.1.4 Summary of Nitrate. The highest nitrate (as nitrogen) concentrations in the vadose zone appear to be confined to the shallow and intermediate depths and to specific areas within the SDA (i.e., around Pad A, the western end of the SDA, the western end of Pit 4, and the Acid Pit) (see Figure 3-33). Concentrations of nitrate (as nitrogen) that exceed upper background levels and the MCL in the vadose zone are not surprising because significant amounts of nitrate salts (i.e., a by-product of the weapons manufacturing process) are buried in the SDA.

No nitrate (as nitrogen) levels above background were detected in any RWMC aquifer monitoring wells. All nitrate (as nitrogen) concentrations measured between 1997 and May 2005 were characteristic of Snake River Plain Aquifer background.

Table 3-91 summarizes concentration ranges, detection rates, and MCL exceedances in FY 2005 for vadose zone soil and aquifer monitoring, and Table 3-92 summarizes the same information for monitoring years 1997 to 2005.

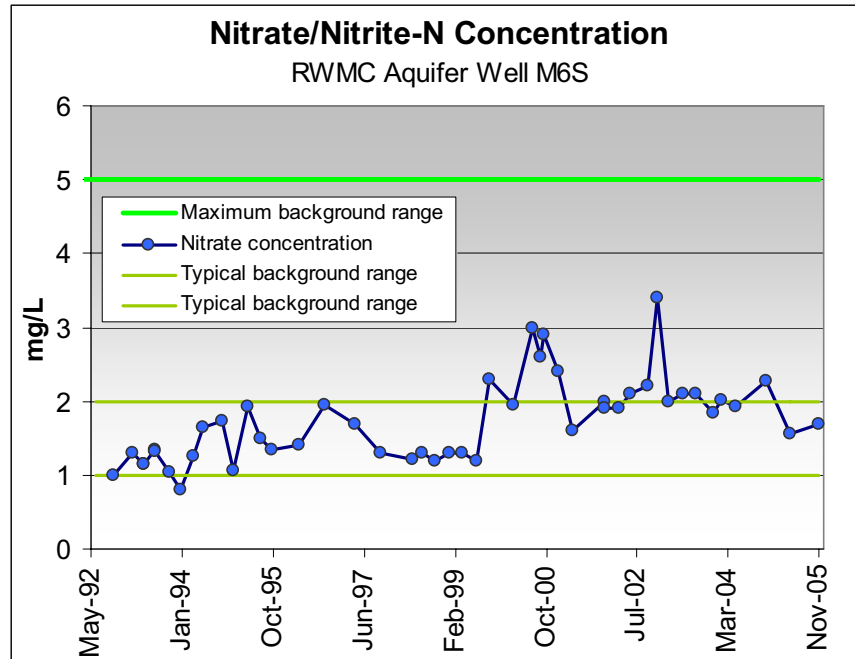


Figure 3-32. Concentration of nitrate (as nitrogen) in Well M6S from 1997 to May 2005.

Figure 3-33. Locations of Fiscal Year 2005 nitrate (as nitrogen) detections at concentrations greater than soil-moisture background.

Table 3-91. Nitrate (as nitrogen) detection frequencies, concentration ranges, and maximum contaminant level exceedances for concentrations greater than upper background levels in Fiscal Year 2005.

Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (mg/L)			
					Minimum	Mean	Maximum	
Vadose zone (0 to 35 ft)								
Soil moisture	40.7	11/27	11	PA02, W08, W23, W25	13.5 _J ^d	31.8	55.6	
Vadose zone (35 to 140 ft)								
Soil moisture	34.5	10/29	10	D06, I-2S, I-4S, TW1	13.1 _R ^d	49.5	116.0 _R ^d	
Vadose zone (140 to 250 ft)								
Soil moisture and perched water	0.0	0/20	0	NA	NA	NA	NA	
Vadose zone (>250 ft)								
Soil moisture	0.0	0/18	0	NA	NA	NA	NA	
Aquifer	0.0	0/34	0	NA	NA	NA	NA	

a. Ratio = number of detections above upper background levels/number of sample analyses.

b. Table 2-2 provides comparison concentrations (i.e., maximum contaminant levels for water).

c. The following nitrate upper background concentrations were applied to the various sample media (see Table 2-2):

- 5.0 mg/L was applied to aquifer and perched water samples
- 11.4 mg/L was applied to soil-moisture samples.

d. Initial analysis met holding-time requirements; however, nitrate concentrations were sufficient to require dilution, and the second analysis missed the holding time. Therefore, these data are flagged with "R" qualifiers. These results are commensurate with historical data and considered usable, but only as estimated quantities.

Table 3-92. Nitrate (as nitrogen) detection frequencies, concentration ranges, and maximum contaminant level exceedances for concentrations greater than upper background levels for sampled media since 1997.

Groundwater in upper Culebra and lower Fort Sampled Media Since 1997							
Sample Media	Detection Rate (%)	Ratio ^a	Number of Detections Greater Than Comparison Concentrations ^b	Wells with Detections Greater Than Comparison Concentration	Range of Detected Concentrations Above Background ^c (mg/L)		
					Minimum	Mean	Maximum
Vadose zone (0 to 35 ft)							
Soil moisture	43.8	67/153	67	98-4, 98-5, D15, PA01, PA02, PA03, W05, W08, W23, W25	12.9	38.5	102.0
Vadose zone (35 to 140 ft)							
Soil moisture	31.0	31/100	31	D06, I-2S, I-4S, TW1	12.0	43.1	116.0 _R ^d
Vadose zone (140 to 250 ft)							
Soil moisture and perched water	4.3	3/69	3	I-2D, USGS-92	5.4	7.7	11.6
Vadose zone (>250 ft)							
Soil moisture	0.0	0/24	0	NA	NA	NA	NA
Aquifer	0.0	0/397	0	NA	NA	NA	NA

a. Ratio = number of detections above upper background levels/number of sample analyses

b. Table 2-2 provides comparison concentrations (i.e., maximum contaminant levels for water).

c. The following nitrate upper background concentrations were applied to the various sample media (see Table 2-2):

- 5.0 mg/L was applied to aquifer and perched water samples
- 11.4 mg/L was applied to soil-moisture samples.

d. Initial analysis met holding-time requirements; however, the nitrate concentration was sufficient to require dilution, and the second analysis missed the holding time. Therefore, the data are flagged with an "R" qualifier. The result is commensurate with historical data and considered usable, but only as an estimated quantity.

3.13.2 Other Inorganic Contaminants

As described in Section 2.2, this annual monitoring report includes only those anions and metals that exhibit sustained concentration trends, or trends that are approaching regulatory limits, or where evidence of migration is perceived. Though not included in this monitoring report, analysis results of all constituents, detections, and nondetections are provided in limitations and validation reports distributed to DOE, the Idaho Department of Environmental Quality, and EPA, and archived in the Idaho Cleanup Project Electronic Document Management System.

In FY 2005, a few anions and metals were detected in vadose zone soil moisture and aquifer samples at concentrations greater than upper background concentration levels. However, concentrations, concentration trends, and locations are typical of historical and previously reported data. Most anions and metals detected above upper background levels in the vadose zone are attributable to magnesium chloride brine; anions and metals consistently detected above background concentrations in the aquifer are chromium, chloride, sodium, and sulfate.

Detections, concentrations, and distributions in the vadose zone and aquifer in FY 2005 and since 1997 are discussed briefly in the following subsections.

3.13.2.1 Vadose Zone. Anions and metals regularly detected at concentrations greater than local background levels in vadose zone soil moisture include bromide, calcium, chloride, sodium, magnesium, potassium, and sulfate. Each of these is attributed to magnesium chloride brine applied to suppress dust on SDA roads in 1984, 1985, 1992, and 1993. Chemical constituents of the brine are now widely distributed in the vadose zone at RWMC and are consistently detected at many locations during routine monitoring of vadose zone soil moisture to depths around 30.5 m (100 ft), with frequent detections at a few locations to depths around 67 m (220 ft). At one location (i.e., Well DE7) brine constituents are consistently detected at depths of 126 m (413 ft). Though brine concentrations are detected at many locations, the only area where concentration trends are evident is in the southeast corner of the SDA at lysimeter Wells 98-1, O-2, and W05.

Brine affects the chemistry of soil water by ion exchange, as evidenced by brine constituents at concentrations above background and changes in anion ratios. Because the chemical constituents of brine are corrosive, they could have enhanced corrosion and release of contaminants from waste in the SDA.

Other anions and metals with concentrations above background often detected include barium at Well DE7; fluoride at Wells IE6, PA01, and PA03; and selenium at Wells D06, PA01, PA02, and 8802D.

3.13.2.2 Aquifer. In FY 2005, anions and metals regularly detected at concentrations greater than aquifer background concentrations include chromium, chloride, sodium, and sulfate. Other anions and metals were detected in the aquifer around RWMC (e.g., aluminum, iron, and magnesium) in FY 2005, but only intermittently and in low concentrations. Chromium, chloride, sodium, and sulfate were primarily detected in monitoring wells located directly south and southeast of the RWMC, in a low-permeability zone (see Figure 3-34). Chloride, sodium, and sulfate concentrations in aquifer monitoring wells around RWMC vary drastically from well to well. Significant concentration trends are associated with these analytes; some are increasing and others are decreasing, depending on the well location. Generally, concentrations of chloride, sodium, and sulfate are decreasing in wells south of RWMC; whereas, chloride and sulfate concentrations in wells upgradient and east of the RWMC are stable, but sodium levels are increasing. Definite dissimilarities are evident in anion (chlorine and sulfate), cation (sodium), and metal (chromium) concentrations and trends in wells south of RWMC versus those located north and east. These data are providing clues to understanding transport through the vadose zone and groundwater beneath RWMC. Recent findings of a 2-year geochemical study conducted

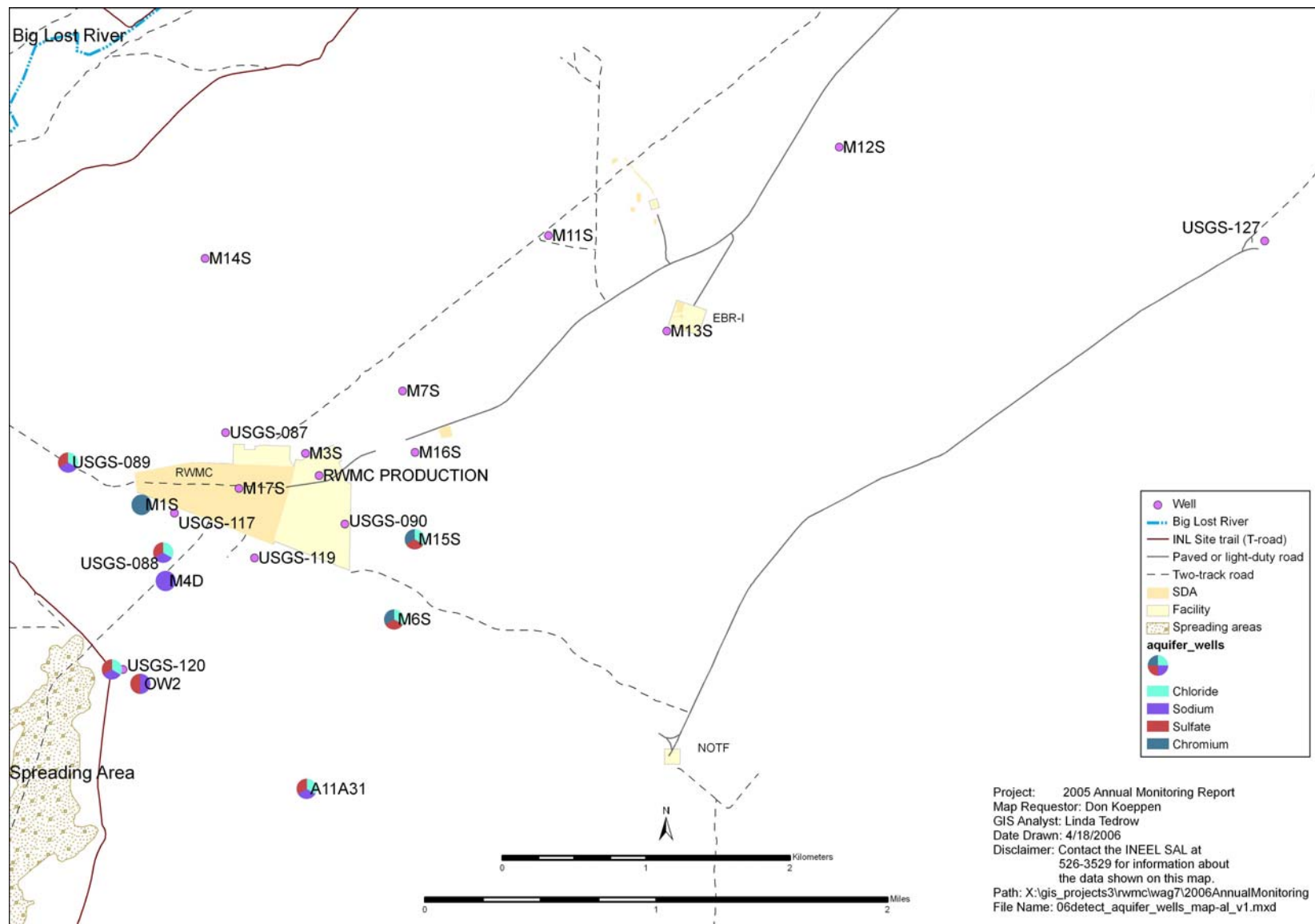


Figure 3-34. Well locations with above background concentrations of chloride, chromium, sodium, and sulfate in Fiscal Year 2005, including Fiscal Year 2004 U.S. Geological Survey data.

by WAG 10 (DOE-ID 2006) indicate anions found above background concentrations in wells south-southeast of RWMC have characteristics suggestive of brine constituents from the SDA; whereas, anions and tritium detected north-northeast of RWMC have signatures characteristic of upgradient facilities (i.e., INTEC and possibly RTC). Additional data (i.e., I-129 analyses by accelerator mass spectrometry) are currently being evaluated; preliminary results support the conclusion that past discharge practices at upgradient facilities have affected water quality at RWMC.

Chromium concentrations at locations M1S, M6S and M15S consistently exceeded the maximum concentration range found in the Snake River Plain Aquifer around the INL Site.

In FY 2005, total chromium concentrations at these three locations ranged from 25.2 µg/L in Well M6S to 122 µg/L in Well M15S. After excluding uncharacteristically high concentrations around the RTC from the USGS data set (Knobel et al. 1999), typical chromium concentrations in the Snake River Plain Aquifer around the INL Site range from 1 to 22 µg/L. Total chromium concentrations in these three RWMC monitoring wells (i.e., Wells M1S, M6S, and M15S) historically exceeded this range. Wells M1SA and M6S have shown a gradually increasing concentration trend over the past 12 years, and Well M15S began its upward trend in the past couple of years (see Figure 3-35).

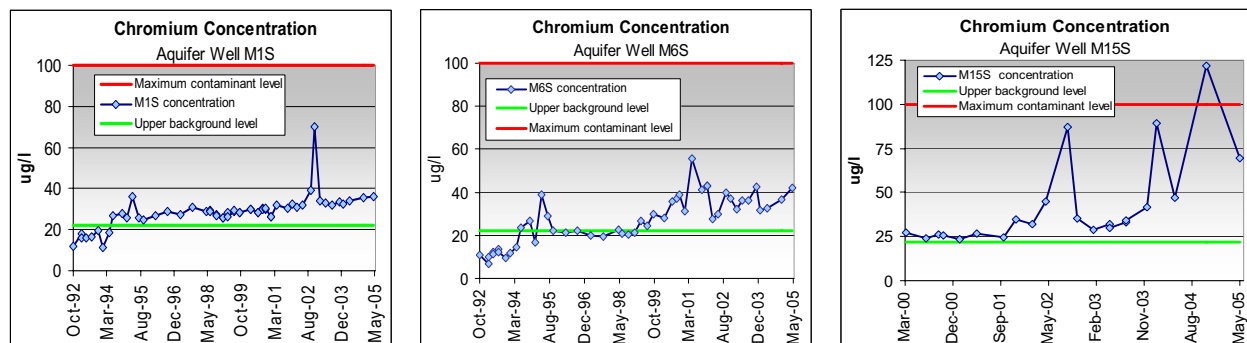


Figure 3-35. Chromium concentration trends at aquifer monitoring Wells M1S, M6S, and M15S.

3.13.2.3 Summary of Other Inorganic Chemicals. Various inorganic chemicals are detected at concentrations substantially above background levels in the vadose zone. Most appear to be attributed to magnesium chloride brine, except for barium, fluoride, and selenium. Brine constituents are fairly widespread throughout the SDA, while barium, fluoride, and selenium are unique to specific areas in the SDA.

Chloride, chromium, sodium, and sulfate are inorganic constituents most consistently detected at concentrations above background in the aquifer around RWMC. Both increasing and decreasing concentration trends are associated with these analytes, depending on well location. Most data show a distinct region south and southeast of RWMC that is uncharacteristic of most other aquifer monitoring wells around RWMC and the INL Site. Also, the region north and northeast of RWMC has anion and cation chemistry very different from that south-southeast. The groundwater study conducted by WAG 10 (DOE-ID 2006) indicates that anions and cations found in wells south-southeast of RWMC have signatures suggestive of brine (or waste) constituents from the SDA; whereas, anions and cations detected north-northeast of RWMC have signatures characteristic of upgradient sources.

3.14 Volatile Organic Compounds

3.14.1 Carbon Tetrachloride

Carbon tetrachloride was identified as a contaminant of potential concern, primarily for the groundwater ingestion exposure pathway for OU 7-13/14. The primary source of carbon tetrachloride at the SDA comprises Series 743 waste drums shipped from the Rocky Flats Plant between 1966 and 1970 (Miller and Varvel 2005). Initially, 9,689 Series 743 waste drums were buried in multiple pits in the SDA, including Pits 4, 5, 6, 9, 10, 11, and 12. In the 1970s, all 1,015 drums from Pits 11 and 12 were retrieved, leaving 8,674 drums of Series 743 waste drums in the SDA. The estimated mass of carbon tetrachloride contained in these 8,674 drums is $7.9\text{E}+05$ kg (Miller and Varvel 2005).

Carbon tetrachloride has been detected at the SDA in vadose zone soil gas, in vadose zone soil water (perched water and lysimeters), and in the aquifer beneath and surrounding the SDA. Carbon tetrachloride vapor also has been detected emanating from the soil surface by surface isolation flux chambers.

3.14.1.1 Vadose Zone

3.14.1.1.1 Perched Water and Lysimeter—In FY 1995, vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

3.14.1.1.2 Soil Gas—An extensive system of permanent soil gas sampling ports inside and outside the SDA boundary are used to monitor soil gas in the vadose zone. The ports are made of stainless steel tubing attached to the outside of well casings. Bottoms of the tubes are perforated and surrounded by sand. Figures 2-6 and 2-7 show the location of wells with soil gas sampling ports near the SDA and depths of the ports, respectively. Port depths range from a minimum of 4.6 m (15 ft) deep in Well WWW 1 to a maximum of 180 m (591 ft) deep just above the water table in Well M13S.

Over 2,100 vadose zone soil-gas samples were collected in FY 2005 and analyzed with a Brüel and Kjær photoacoustic multigas analyzer. Nearly one-half of all detections were less than 10 ppmv, and 46 detections were greater than 1,000 ppmv.

The maximum carbon tetrachloride concentration measured in FY 2005 was 611 ppmv in Well D02, Port 3, at a depth of 21 m (69 ft), on October 6, 2004. Values for Well 8902, which had the maximum value for FY 2004, ranged between 2 and 40 ppmv. The maximum value for carbon tetrachloride for FY 2005 is significantly less than the highest concentration measured in vadose zone monitoring wells, which was 4,864 ppmv in nearby Well 9302, Port 6, at a depth of 23.5 m (77 ft) in January 1995. The highest levels of carbon tetrachloride are located in the central portion of the SDA between Pits 4, 5, 6, and 10 and decrease with distance away from this area. Concentrations in the wells farthest from the SDA (i.e., Wells OCVZ-11, and OCVZ-13) are less than 1 ppmv.

Vertically, the carbon tetrachloride soil-gas contamination extends from land surface down to the water table. Currently, in the center of the SDA, carbon tetrachloride concentrations can be 1,000 ppmv or higher above the B C interbed. Concentrations then decrease sharply across the B-C interbed down to a few hundred ppmv. Below the C D interbed, concentrations are generally less than 50 ppmv. However, it appears that when the vapor vacuum extraction with treatment system is extracting from deep extraction wells, maximum concentrations are reduced to approximately 20 ppmv or less.

Overall, the organic vapor concentrations at most locations are much less now than before full-time operation of the Organic Contamination in the Vadose Zone Project vacuum extraction with treatment system began in January 1996. Figures 3-36 and 3-37 show soil-gas concentrations at two wells (i.e., Wells 8801 and 9301) near vapor extraction Well 8901D. In 1993, a treatability study was performed and soil gas extraction from Well 8901D was performed for approximately 3 months. This event had little lasting impact on concentration levels. Before 1996, the carbon tetrachloride concentration at approximately 23.5 m (77 ft) deep (above the B-C interbed) was approximately 3,000 ppmv in these two wells. However, after full-time extraction began in January 1996, the concentration dropped to about 1,000 ppmv. Near the 40-m (130-ft) depth, below the B-C interbed, the concentration dropped from about 600 ppmv before vapor vacuum extraction operations to 100 ppmv after operations. Concentrations in the deeper ports, around 70 m (230 ft) deep, appear to be unchanged by operations. In Well 9V (see Figure 3-38), the initial drop in concentration was not so dramatic, probably because it is located farther from an extraction well; however, the decrease has been steady. Even the deep gas port at 68 m (223 ft) bls shows a clear decline in concentrations.

In FY 2005, vadose zone soil-gas concentrations showed an overall decrease over FY 2004 levels. Vapor-vacuum extraction with treatment Units D, E, and F operated continuously during FY 2005; this accounts for the reductions observed, as shown in Figures 3-36, 3-37, and, to a lesser degree, in Figure 3-38.

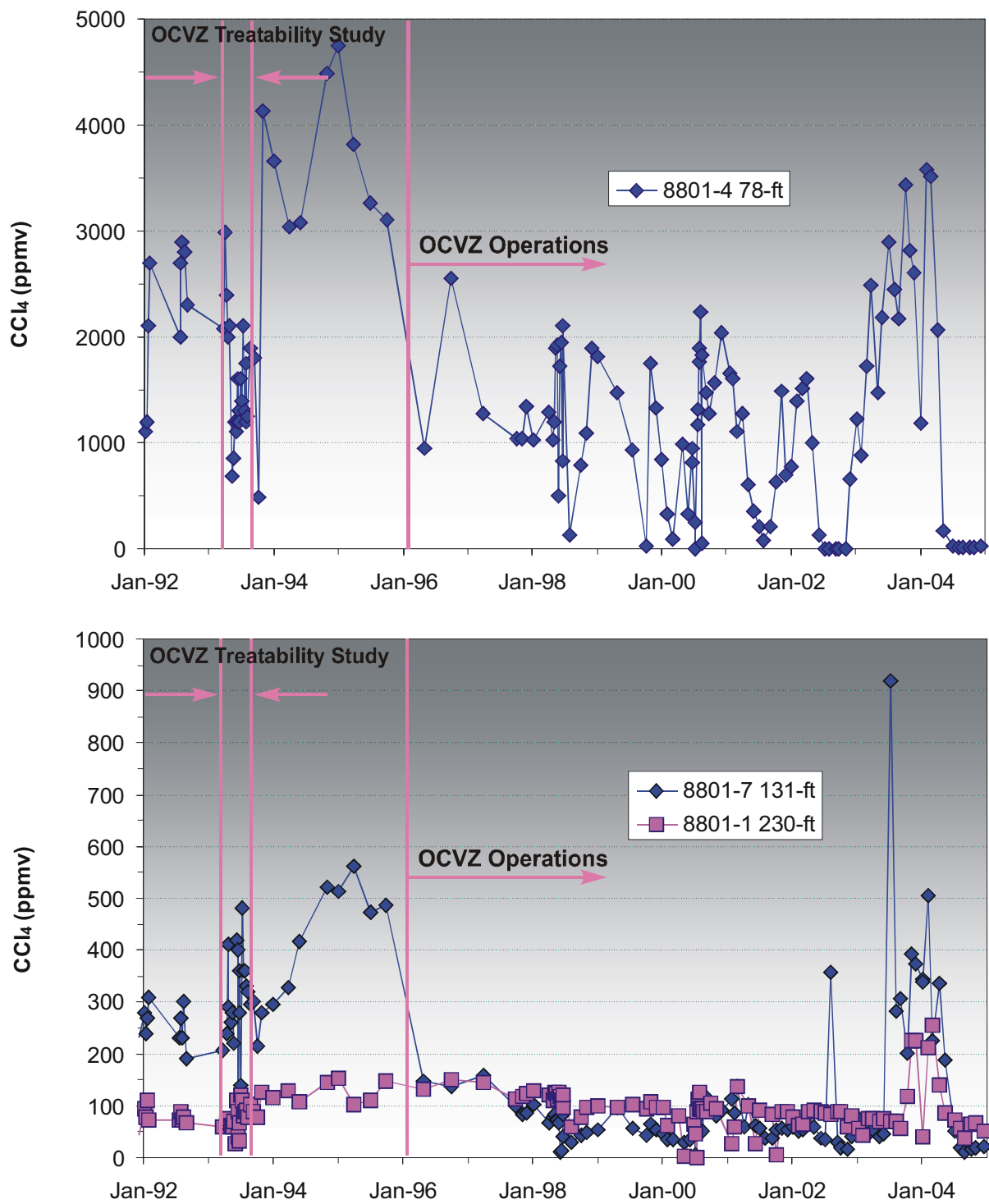


Figure 3-36. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 8801.

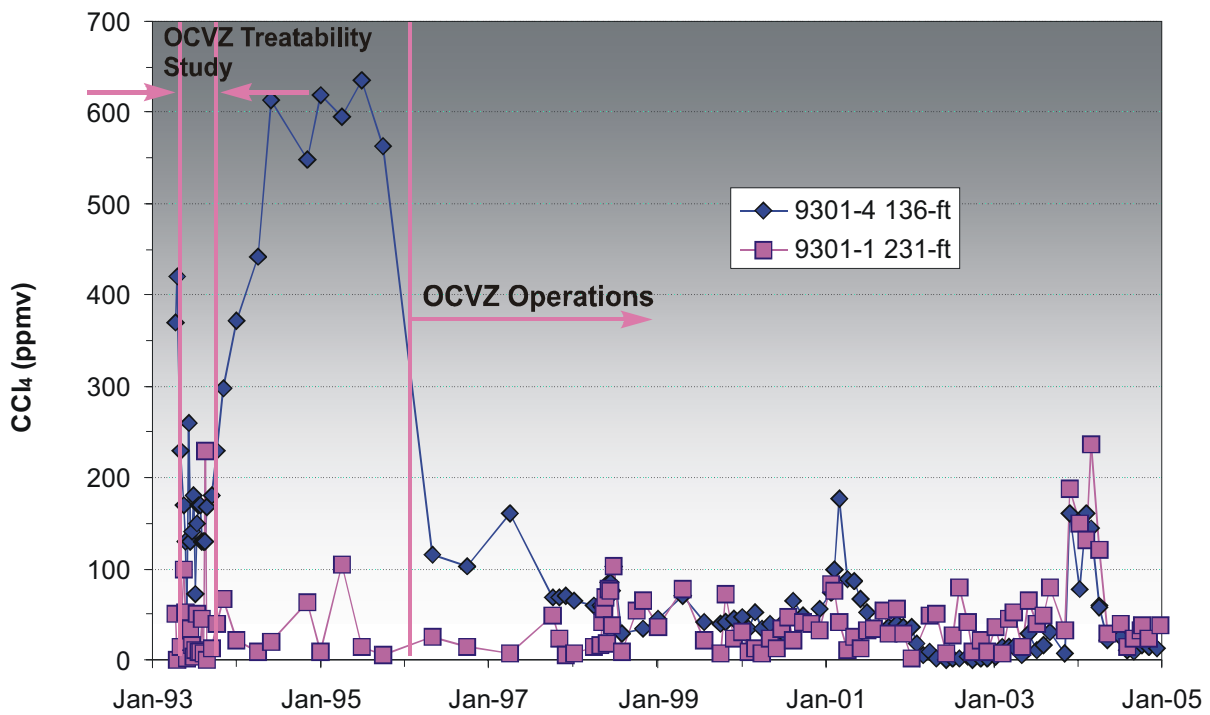
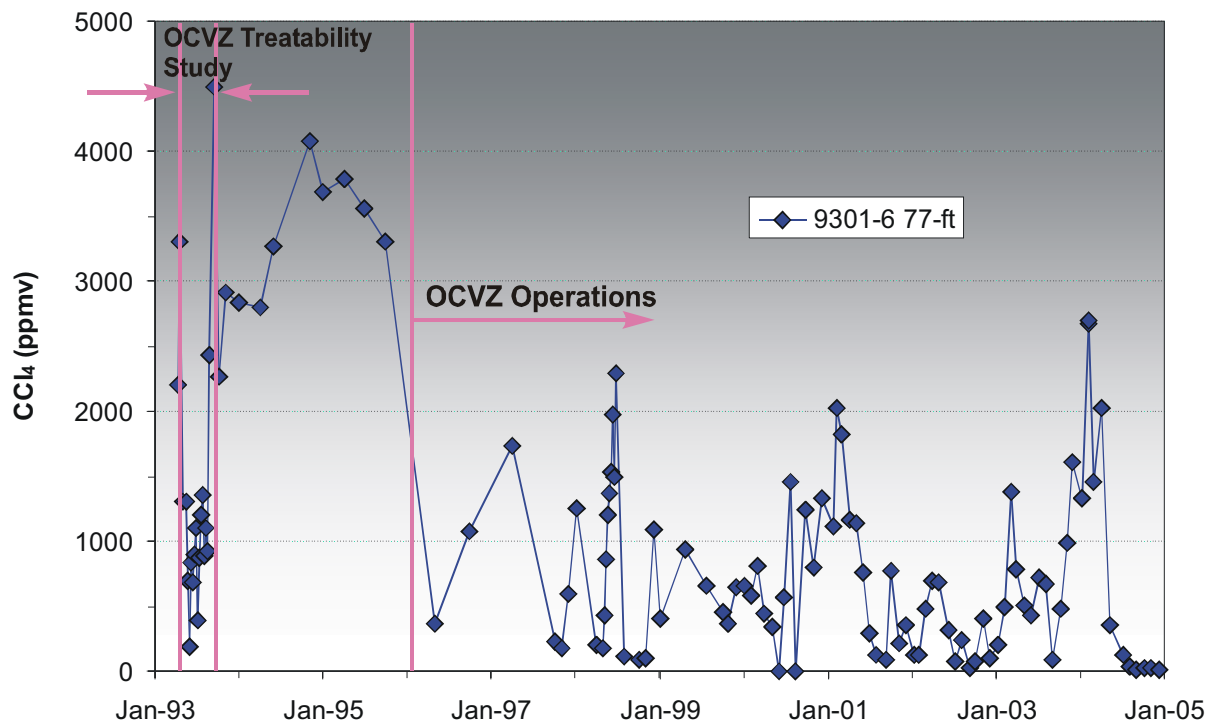


Figure 3-37. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9301.

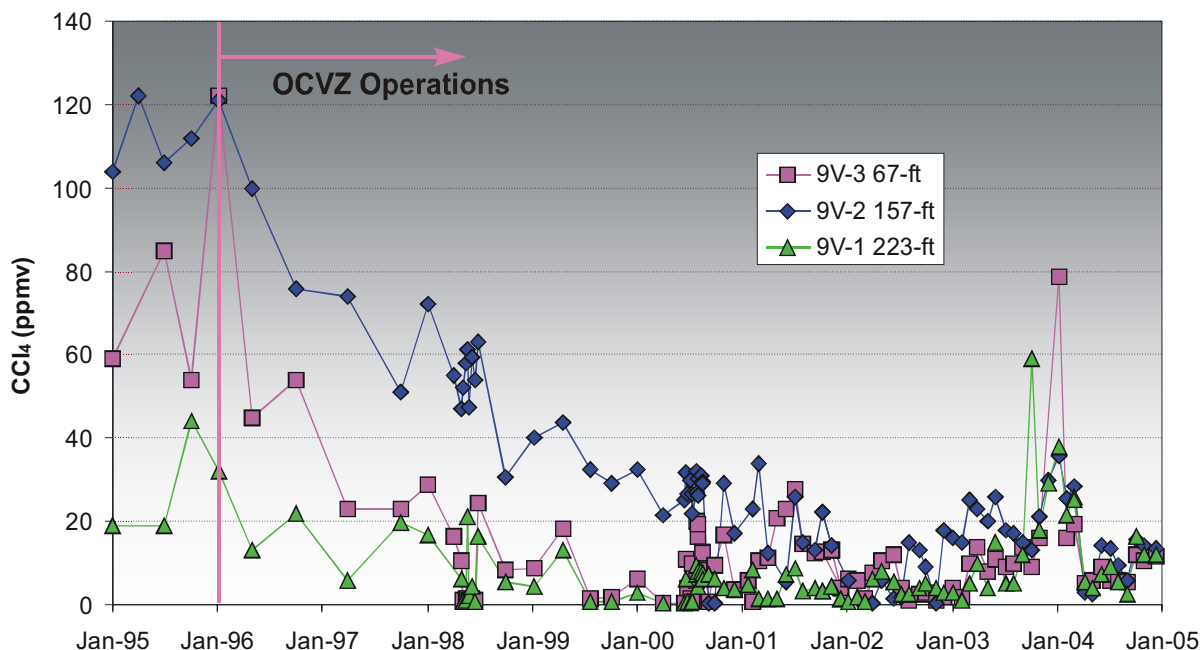


Figure 3-38. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9V.

3.14.1.2 Aquifer. In FY 2005, 169 samples were collected from 16 monitoring wells near RWMC and analyzed for VOCs. Thirty-two of the samples were collected by WAG 7 personnel from 15 monitoring wells and analyzed for carbon tetrachloride. Twenty-two of those 34 samples (i.e., 65%) had detections above the quantitation limit of 1 µg/L. Of those 22 detections, two (i.e., 9%) exceeded the primary drinking water MCL of 5 µg/L, down from 7% (two out of 29) in FY 2004. Samples were collected by WAG 7 in November and December 2004 and April and May 2005 from monitoring Wells A11A31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. Table 3-93 summarizes WAG 7 aquifer sampling results above the quantitation limit.

Table 3-93. Carbon tetrachloride results above quantitation limit or minimum reporting level in the aquifer monitoring wells in Fiscal Year 2005.

Well	Date Collected	Carbon Tetrachloride ^a (µg/L)	Quantitation Limit or Minimum Reporting Level ^b (µg/L)
RWMC Production	10/20/2004	4.9	1
M17S	10/29/2004	1.5	1
M17S	10/29/2004	1.6	1
M15S	10/29/2004	1.9	1
OW2	11/22/2004	0.71 ^c	1
A11A31	11/22/2004	3.2	1
M6S	11/23/2004	2	1
M7S	11/23/2004	6.4 ^d	1
M7S	11/23/2004	6.5 ^d	1

Table 3-93. (continued).

Well	Date Collected	Carbon Tetrachloride ^a (µg/L)	Quantitation Limit or Minimum Reporting Level ^b (µg/L)
M14S	11/30/2004	0.85 ^c	1
M16S	11/30/2004	4.2	1
M3S	12/01/2004	2.7	1
RWMC Production	01/25/2005	5	1
RWMC Production	04/19/2005	5.6^d	1
A11A31	04/25/2005	3	1
OW2	04/25/2005	0.36 ^c	1
M14S	04/27/2005	0.64 ^c	1
M6S	04/27/2005	2 ^c	1
M3S	04/28/2005	2.5 ^c	1
M7S	05/03/2005	4.6 ^c	1
M7S	05/03/2005	5 ^c	1
M16S	05/04/2005	3.1 ^c	1
M15S	05/04/2005	1.8 ^c	1
M17S	05/05/2005	1 ^c	1
M17S	05/05/2005	1.1 ^c	1
RWMC Production	07/20/2005	4.6	1

a. Waste Area Group 7 results.

b. Quantitation limit or minimum reporting level is the lowest concentration that can be reliably measured in a sample with suitable precision and accuracy.

c. Indicates concentrations assigned a "J" data qualifier flag. The qualifier flag was assigned because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should be used only as estimated quantities.

d. **Bold font** indicates the value exceeded drinking water the maximum contaminant level of 5 µg/L.

No USGS data were available for the reporting period. However, there were 135 samples collected from the RWMC Production Well by drinking water surveillance program personnel, and carbon tetrachloride was present in one sample taken on April 19, 2005, at concentrations above the MCL of 5 µg/L. Data from drinking water monitoring are provided for comparison only.

3.14.1.3 Summary of Carbon Tetrachloride. When RWMC Production Well data were included with FY 2005 data of 15 WAG 7 monitoring wells, carbon tetrachloride was consistently detected in nine of 16 aquifer monitoring wells. Concentrations in these wells varied from 0.71 to 6.5 µg/L, with two wells (i.e., Wells M7S and RWMC Production) exceeding the MCL. This is consistent with the same two wells in FY 2004. Carbon tetrachloride was detected in FY 2005 in vadose zone soil gas and in the aquifer in and around RWMC. No perched water samples obtained in FY 2005 were analyzed for organics due to limited sample volumes. The maximum carbon tetrachloride concentration measured in FY 2005 was 611 ppmv in Well D02, Port 3, at a depth of 21.m (69 ft) on October 6, 2004. Carbon tetrachloride concentrations in vadose zone soil gas are appreciably lower since the Organic Contamination in the Vadose Zone Project began operation of the vapor vacuum extraction with treatment system.

In FY 2005, low levels of carbon tetrachloride were consistently detected in aquifer monitoring wells in and around RWMC. The maximum concentration was 6.5 µg/L, measured in Well M7S. This well contained the only measured concentration that exceeded the MCL of 5 µg/L. This is down from two wells in FY 2004 and four wells in FY 2003. However, no USGS or Production Well data were available for FY 2005. Although concentrations in some wells have increased over the past several years, data indicate a relatively flat and perhaps slightly declining trend in many wells during the past few years.

3.14.2 Methylene Chloride

Methylene chloride was identified as a contaminant of potential concern, primarily for the groundwater ingestion exposure pathway for OU 7-13/14. Approximately 1.4E+04 kg of methylene chloride was buried in the SDA (Holdren et al. 2002). Information about methylene chloride disposal is scant compared to that for other, more prevalent VOCs (e.g., carbon tetrachloride). It should be noted that methylene chloride is a degradation byproduct of carbon tetrachloride; thus, considering the large mass of carbon tetrachloride buried in the SDA, detections of methylene chloride in samples might not necessarily be related to the original inventory buried in the SDA.

3.14.2.1 Vadose Zone

3.14.2.1.1 Perched Water and Lysimeter—Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2005 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

3.14.2.1.2 Soil Gas—None of the soil-gas samples collected from the vadose zone vapor sampling ports since FY 2001 were analyzed for methylene chloride. However, of the hundreds of samples collected before FY 2002 and analyzed for methylene chloride, only five returned positive detections, and the concentrations were relatively low compared to other VOCs (e.g., carbon tetrachloride, chloroform, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethylene).

3.14.2.2 Aquifer. In FY 2005, 169 aquifer samples were collected from 16 monitoring wells near RWMC and analyzed for VOCs. Twenty of the samples were collected from 15 monitoring wells (i.e., Wells A1A31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). None of the 169 samples had a detection of methylene chloride above the quantitation limit of 1 µg/L. Data from USGS wells were not available for this reporting period.

Positive detections of methylene chloride are infrequent in aquifer monitoring wells near the SDA. The maximum historical methylene chloride concentration measurement (collected on July 22, 1996) was 8 µg/L in Well M10S, which is greater than the MCL of 5 µg/L. However, five of the seven historical detections resulted from the same sampling round (July 1996); this raises the question as to whether the samples were cross-contaminated before or during analysis. Methylene chloride was reported at 2.8 µg/L in Well M1S in November 2002, but was also detected in the associated blank. Except for this incident, methylene chloride has not been detected in any aquifer monitoring wells since October 1997. Some positive detections may also be attributed to analytical protocol, as methylene chloride is a common laboratory contaminant.

3.14.2.3 Summary of Methylene Chloride. No lysimeter, perched water, or vadose zone soil-gas samples were analyzed for methylene chloride in FY 2005. No methylene chloride was detected above the quantitation limit of 1 µg/L in the 169 aquifer samples collected in WAG 7 wells.

3.14.3 Tetrachloroethylene

Tetrachloroethylene was identified as a contaminant of potential concern, primarily for the groundwater ingestion exposure pathway for OU 7-13/14. Series 743 waste is the primary source of tetrachloroethylene at the SDA. The estimated mass of tetrachloroethylene contained in Series 743 sludge buried in the SDA is $9.87\text{E}+04$ kg (Varvel 2005).

Tetrachloroethylene has been detected at the SDA in surficial sediments, vadose zone soil gas, vadose zone soil water (perched water and lysimeters), and groundwater. Surface isolation flux chambers also detected tetrachloroethylene vapor emanating from the soil surface.

3.14.3.1 Vadose Zone

3.14.3.1.1 Perched Water and Lysimeter—In FY 2005, vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

3.14.3.1.2 Soil Gas—Tetrachloroethylene has been detected consistently in soil gas at RWMC for several years, but at much lower concentrations than carbon tetrachloride. Before FY 2002, the historic maximum tetrachloroethylene concentration was 135 ppmv in Well 8902, Port 4, at 39 m (130 ft) deep, on January 4, 1996. This was immediately prior to the vapor vacuum extraction with treatment system beginning full-scale operations. Since April 1998, the tetrachloroethylene concentrations in Well 8902, Port 4, have been less than 10 ppmv.

Since June 2002, several anomalously high tetrachloroethylene measurements have occurred, almost exclusively at Wells 77-1 and 78-4. Validity of these results is highly questionable for two reasons. First, the wells are more than 305 m (1,000 ft) from an organic sludge disposal area. Second, just before the dramatic increase in concentration at these wells, sulfur hexafluoride gas was used for a gas tracer test in these two wells. It is very likely that the sulfur hexafluoride interferes with the tetrachloroethylene filter on the Brüel and Kjær gas analyzer. The number of anomalous readings has decreased since the tracer test, but they still persist. The maximum tetrachloroethylene concentration in soil gas in FY 2005 was 95.5 ppmv in Well 77-1, Port 2, at 58 m (190 ft) deep, on February 8, 2005. The tetrachloroethylene concentration in soil gas for Well 77-1, Port 4, for FY 2005, ranged from 25.8 to 84.2 ppmv. Because tetrachloroethylene concentrations at this location before the sulfur hexafluoride tracer test were less than 20, it appears that the sulfur hexafluoride interference still persists.

The majority of tetrachloroethylene results were quite low. For example, of all tetrachloroethylene vadose zone soil-gas results in FY 2005, 86.9% were less than 5 ppmv.

3.14.3.2 Aquifer. In FY 2005, 169 aquifer samples were collected from 16 monitoring wells near RWMC and were analyzed for VOCs. Thirty-four of the samples were collected by WAG 7 personnel from 15 monitoring wells (i.e., Wells A11A31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). None of the 169 samples had tetrachloroethylene detections above the quantitation limit of 1 µg/L. Four of the samples, which were collected from Well M7S, had estimated concentrations (J flag) of 0.39, 0.40, 0.43 and 0.46 µg/L. Data from USGS wells were not available for this reporting period. Samples from USGS RWMC Production Well drinking water monitoring group showed no detections of tetrachloroethylene.

Positive detections of tetrachloroethylene in the SDA-vicinity aquifer monitoring wells are infrequent. Confirmed detections are far below the MCL of 5 µg/L.

3.14.3.3 Summary of Tetrachloroethylene. Tetrachloroethylene was detected in FY 2005 in vadose zone soil gas and in the aquifer near RWMC. The maximum tetrachloroethylene concentration in vadose zone soil gas was 96 ppmv. Over 86% of the tetrachloroethylene soil-gas results were less than 5 ppmv.

Positive detections of tetrachloroethylene in the SDA-vicinity aquifer monitoring wells are infrequent. The maximum aquifer concentration measured in FY 2005 was an estimated (“J” flag) concentration of 0.46 µg/L for Well M7S, but this is below the quantitation limit of 1 µg/L. Aquifer results are consistent, with the FY 2004 results indicating no increasing or decreasing trend.

3.14.4 Other Volatile Organic Compounds

Series 743 waste is known to contain other organic compounds (e.g., 1,1,1-trichloroethane and tetrachloroethylene). These organic compounds have been detected in virtually all media in and around the SDA. The estimated mass of 1,1,1-trichloroethane and tetrachloroethylene in Series 743 sludge is 8.19E+04 kg and 8.92E+04 kg, respectively (Varvel 2005). Chloroform detections are also prevalent at the SDA, but records indicate very little chloroform was buried. Most of the chloroform is believed to be a degradation product of carbon tetrachloride. Disposal amounts of other organic compounds are very small compared to the amounts in Series 743 sludge.

3.14.4.1 Vadose Zone

3.14.4.1.1 Perched Water and Lysimeter—Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2005 due to limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

3.14.4.1.2 Soil Gas—Chloroform, 1,1,1-trichloroethane, and trichloroethylene are the only other VOCs for which analysis is performed on vadose zone soil-gas samples routinely collected at the SDA. All three compounds are ubiquitous near RWMC, but at much lower concentrations than carbon tetrachloride. Nevertheless, the trends are very similar to carbon tetrachloride concentrations. The detection for chloroform, 1,1,1-trichloroethane, and trichloroethylene in vadose zone soil-gas samples collected during FY 2005 were generally less than 5 ppmv. The percentage of detections less than 5 ppmv were chloroform (i.e., 58.6%), 1,1,1-trichloroethane (i.e., 90.4%), and trichloroethylene (i.e., 70.9%).

Table 3-94 shows maximum concentrations of chloroform, 1,1,1-trichloroethane, and trichloroethylene detected in FY 2005 both inside and outside the SDA.

Table 3-94. Maximum concentrations of trichloroethylene, 1,1,1-trichloroethane, and chloroform detected in vadose zone soil gas inside and outside the Subsurface Disposal Area in Fiscal Year 2005.

Organic Compound	Inside or Outside the Subsurface Disposal Area	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Chloroform	Inside	6/1/05	D02-3	69	192
1,1,1-Trichloroethane	Inside	10/6/04	1E-6	36	102
Trichloroethylene	Inside	10/6/04	D02-3	69	138
Chloroform	Outside	8/2/05	1898-1	283	23
1,1,1-Trichloroethane	Outside	7/5/05	1898-1	283	13
Trichloroethylene	Outside	7/5/05	1898-1	283	17

3.14.4.2 Aquifer. In addition to carbon tetrachloride, tetrachloroethylene, and methylene chloride, RWMC aquifer samples in FY 2005 were analyzed for other VOCs, and most analyses resulted in nondetections. Chloroform, 1,1,1-trichloroethane, trichloroethylene, and toluene were the only compounds detected at concentrations above the quantitation limit in WAG 7 wells. All compounds were below the respective MCLs. Table 3-95 contains the results for all detections of other organics from aquifer samples. Data from the RWMC Production Well were not available for this report.

Chloroform detected in the RWMC Production Well drinking water sample was above a quantitation limit of 1 µg/L. Data for USGS wells were not available for FY 2005. The maximum concentration of chloroform in FY 2005 was 1.1 µg/L, down from 1.4 µg/L in FY 2004. Trichloroethylene was detected in Wells A11A31, M7S, and M16S above a quantitation limit of 1 µg/L. The maximum concentration in FY 2005 was 2.5 µg/L, down from 3 µg/L in FY 2004. 1,1,1-Trichloroethane was not detected in any WAG 7 monitoring wells above a quantitation limit of 1 µg/L. The maximum 1,1,1-trichloroethane concentration in FY 2005 was 0.55 µg/L, up slightly from 0.5 µg/L in FY 2004. Toluene was detected consistently in Wells M7S, M15S, and A11A31, and the maximum concentration in FY 2005 was 7.6 µg/L, down from 24 µg/L in FY 2004. Samples were analyzed for up to 54 other organic compounds, but none were detected above the quantitation limits in WAG 7 wells.

3.14.4.3 Summary of Other Volatile Organic Compounds. Other organics detected during sampling at RWMC include chloroform, 1,1,1-trichloroethane, trichloroethylene, Freon-113, 1,1-dichloroethane, chloromethane, and toluene. All organics, except for toluene, were detected in waste zone soil gas.

During aquifer monitoring in FY 2005, only four other organic compounds (i.e., 1,1,1-trichloroethane, tetrachloroethylene, chloroform, and toluene) were detected in 204 samples. All sample results were below MCLs. Toluene had the highest concentration (i.e., 7.6 µg/L) measured in Well M14S. The maximum concentrations for trichloroethylene (i.e., 2.5 µg/L), chloroform (i.e., 0.73 µg/L), and 1,1,1-trichloroethane (i.e., 0.55 µg/L) were all from Well M7S.

Detections of 1,1,1-trichloroethane and tetrachloroethylene are not surprising because both were components of Series 743 sludge. Chloroform detections also are not surprising because it is probably being produced by degradation of carbon tetrachloride. Detections of other organics (e.g., Freon-113 and 1,1-dichloroethane [in soil gas], and toluene [in groundwater]) are low-level detections and will continue to be monitored.

Table 3-95. Concentration of other volatile organic compounds detected in aquifer monitoring wells in Fiscal Year 2005.

Organic Compound	Date Collected	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	Maximum Contaminant Level (µg/L)
1,1,1-Trichloroethane	11/23/2004	M7S	0.54 ^a	1	5
	11/23/2004	M7S	0.55 ^{a,b}	1	5
	11/30/2004	M16S	0.39 ^a	1	5
	05/03/2005	M7S	0.5 ^a	1	5
	05/03/2005	M7S	0.49 ^a	1	5
Chloroform	10/20/2004	RWMC Production	0.9 ^c	1	100
	11/22/2004	A11A31	0.68 ^a	1	100
	11/23/2004	M7S	0.67 ^a	1	100
	11/23/2004	M7S	0.73 ^a	1	100
	11/30/2004	M16S	0.47 ^a	1	100
	01/25/2005	RWMC Production	1.1 ^{b,c}	1	100
	04/25/2005	A11A31	0.57 ^a	1	100
	05/03/2005	M7S	0.61 ^a	1	100
	05/03/2005	M7S	0.67 ^a	1	100
	05/04/2005	M16S	0.4 ^a	1	100
	05/04/2005	M15S	0.31 ^a	1	100
Toluene	10/29/2004	M15S	1.5	1	1,000
	11/22/2004	A11A31	1.5	1	1,000
	11/23/2004	M7S	0.72 ^a	1	1,000
	11/23/2004	M7S	0.81 ^a	1	1,000
	11/30/2004	M14S	7.6 ^b	1	1,000
	05/03/2005	M7S	2.3 ^a	1	1,000
	05/03/2005	M4D	2.4 ^a	1	1,000
	05/04/2005	M15S	3.2 ^a	1	1,000
	05/05/2005	M17S	3.6 ^a	1	1,000
	05/05/2005	M17S	3.3 ^a	1	1,000

Table 3-95. (continued).

Organic Compound	Date Collected	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	Maximum Contaminant Level (µg/L)
Trichloroethylene	10/29/2004	M15S	0.74 ^a	1	5
	11/22/2004	A11A31	1.4	1	5
	11/23/2004	M6S	0.47 ^a	1	5
	11/23/2004	M7S	2.2	1	5
	11/23/2004	M7S	2.3	1	5
	11/30/2004	M16S	1.8	1	5
	12/01/2004	M3S	0.7 ^a	1	5
	04/25/2005	A11A31	1.6	1	5
	04/27/2005	M6S	0.5 ^a	1	5
	04/28/2005	M3S	0.67 ^a	1	5
	05/03/2005	M7S	2.4	1	5
	05/03/2005	M7S	2.5	1	5
	05/04/2005	M16S	1.5	1	5
	05/04/2005	M15S	0.84 ^a	1	5
	05/05/2005	M17S	0.31 ^a	1	5
	10/20/2004	RWMC Production	2.2 ^c	1	5
	01/25/2005	RWMC Production	2.6 ^{b,c}	1	5
	04/19/2005	RWMC Production	2.4 ^c	1	5
	07/20/2005	RWMC Production	2.2 ^c	1	5

a. Concentration has an associated "J" data qualifier flag. The qualifier flag was assigned because the recovery of one of the surrogates was slightly above the upper control limit. The volatile organic compound was positively identified in the sample; however, reported concentrations might not be accurate representations of the amount actually present in the sample and should only be used as estimated quantities. As a result, "J" flag data were not considered for the maximum concentration level.

b. **Bold font** indicates the maximum concentration detected.

c. Data presented are from drinking water samples and are not U.S. Geological Survey data.

3.15 Summary of the Nature and Extent of Contamination for Fiscal Year 2005

This summary is a general overview of relevant analytes (see definition in Section 2.1) detected in FY 2005 at concentrations exceeding (or approaching) primary drinking water MCLs. For contaminants or sample media where drinking water MCLs are not applicable (e.g., soil gas), a citation is made if detected concentrations were unusually high or trending. Further information is available in respective sections for each reported contaminant.

In FY 2005, monitoring results from the vadose zone and aquifer indicate that some contaminants have migrated out of the waste zone and into the vadose zone; however, most of these contaminants did not impact the aquifer beneath the RWMC.

In vadose zone soil-moisture samples, nitrate (as nitrogen) and uranium were the only relevant analytes (see definition in Section 2.1) that consistently exceeded the MCL (see Table 3-96). Other relevant analytes were detected in the vadose zone soil-moisture samples; however, concentrations were below MCLs. Analytes detected below MCLs in vadose zone soil moisture include tritium, C-14, Cl-36, Sr-90, and Tc-99 (see Table 3-96). Many low-level C-14 detections occurred in the 35- to 250-ft depth interval this fiscal year, as compared to previous years.

In vadose zone soil-gas samples, high levels of C-14 and tritium were detected at SVRs 12 and 20. Ambient air sampling over SVR 20 continues to show that tritium is being released into the atmosphere at elevated concentrations. In addition, high concentrations of carbon tetrachloride, tetrachloroethylene, and trichloroethylene were detected in vadose zone soil-gas samples (see Table 3-96).

In the aquifer beneath RWMC, carbon tetrachloride was the only relevant analyte consistently detected at concentrations near and occasionally exceeding the primary drinking water MCL in FY 2005 (see Table 3-97). Tritium was another relevant analyte consistently detected in the aquifer at RWMC; however, concentrations are far below the drinking water MCL. The source of the small, isolated tritium plume in the aquifer at RWMC has been identified as originating from upgradient facilities (primarily INTEC) and not from the SDA. The influence from upgradient sources also may explain the slightly higher number of C-14 detections observed in monitoring wells upgradient of RWMC (i.e., Wells M3S, M7S, M12S, and M13S).

Table 3-96. Summary of vadose zone sampling and analyses data for relevant analytes in Fiscal Year 2005.

Relevant Analyte	Lysimeters, Perched Wells, or Vapor Ports Sampled	Analyses	Detections	Maximum Concentration		Detections Greater Than Maximum Contaminant Level	
				pCi/L $\pm 1\sigma$	Other Unit Types	Number	Well Name
Am-241	54	132	0	NA	NA	0	NA
C-14	55	149	22	152 \pm 10	NA	0	NA
C-14 (soil gas) ^a	11	33	30	NA	133,490 pCi[C-14]/g [carbon]	NA	NA
Cl-36	47	105	2	28 \pm 8	NA	0	NA
Cs-137	58	154	0	NA	NA	0	NA
Tritium	52	127	47	NA	NA	0	NA
Tritium (soil gas) ^a	8	58	58	NA	8,342 pCi/mL	NA	NA
I-129	53	114	0	NA	NA	0	NA
Nb-94	58	155	0	NA	NA	0	NA
Np-237	43	88	0	NA	NA	0	NA
Pb-210 ^b	NA	NA	NA	NA	NA	NA	NA
Pu-238	54	132	0	NA	NA	0	NA
Pu-239/240	54	132	0	NA	NA	0	NA
Ra-226 ^b	58	154	0	NA	NA	0	NA
Ra-228 ^b	NA	NA	NA	NA	NA	NA	NA
Sr-90	31	31	2	7.4 \pm 1.1	NA	0	NA
Tc-99	58	153	5	872 \pm 18	NA	0	NA
Th-228	NA	NA	NA	NA	NA	NA	NA
U-233/234	54	132	36 ^c	100 \pm 8	NA	NA ^d	NA
U-235/236	54	132	17 ^c	9.5 \pm 1.4	NA	NA ^d	NA
U-238	54	132	44 ^c	49 \pm 4	NA	NA ^d	NA

Table 3-96. (continued).

Relevant Analyte	Lysimeters, Perched Wells, or Vapor Ports Sampled	Analyses	Detections	Maximum Concentration		Detections Greater Than Maximum Contaminant Level	
				pCi/L $\pm 1\sigma$	Other Unit Types	Number	Well Name
Total uranium ^c	54	132	44 ^c	146 \pm 13	NA	28	98-5, D06, IE6, IIS, PA01, PA02, PA03, R1935, R1936, TW1, W06, W08, W23
Carbon tetrachloride (soil gas) ^f	236	2,100	NA	NA	611 ppmv	NA	NA
1,4-Dioxane (soil gas) ^f	NA	NA	NA	NA	NA	NA	NA
Methylene chloride (soil gas) ^f	236	2100	NA	NA	NA	NA	NA
Nitrate	48	94	21 ^g	116	NA	21	D06, I-2S, I-4S, PA02, TW1, W08, W23, W25
Tetrachloroethylene (soil gas) ^f	236	2100	NA	NA	95.5 ppmv	NA	NA
Trichloroethylene (soil gas) ^f	236	2100	NA	NA	138 ppmv	NA	NA

a. Soil-gas monitoring near buried activated stainless steel and beryllium blocks in SVRs 12 and 20.
b. Monitoring is not performed directly for some analytes.
c. U-234, -235, and -238 are naturally occurring in the environment, and the number of detections shown are for results that exceeded local soil-moisture upper background concentrations. Soil-moisture background concentrations of 8.52, 1.34, and 3.86 are upper concentration comparison values for U-233/234, U-235/236, and U-238, respectively, above which uranium sample data are reported.
d. Primary drinking water maximum contaminant level is not applicable to each individual uranium isotope, but to total uranium only.
e. Total uranium derived by converting isotopic uranium results (pCi/L) to mass units (µg/L) and summing the results.
f. Soil-gas samples are collected in the vadose zone from sampling ports that range in depth from 4.6 m (15 ft) to 180 m (591 ft) deep.
g. Nitrate (as nitrogen) is naturally occurring in the environment, and the number of detections shown are for results that exceeded the local soil-moisture upper background concentration value of 11.4 mg/L.

Table 3-97. Summary of aquifer sampling and analyses data for relevant analytes in Fiscal Year 2005.

Relevant Analyte	Monitoring Wells Sampled	Analyses	Detections	Maximum Concentration	Detections Greater Than Maximum Contaminant Level	
					Number	Well Name
Am-241	15	35	0	NA	0	NA
C-14	15	34	0	NA	0	NA
Cl-36	15	35	0	NA	0	NA
Cs-137	15	35	0	NA	0	NA
Tritium	15	34	19	1,440 ± 91 pCi/L (1σ)	0	NA
I-129	15	34	0	NA	0	NA
Nb-94 ^a	15	35	0	NA	0	NA
Np-237	15	35	0	NA	0	NA
Pb-210 ^a	NA	NA	NA	NA	NA	NA
Pu-238	15	35	0	NA	0	NA
Pu-239/240	15	35	0	NA	0	NA
Ra-226 ^a	15	35	0	NA	0	NA
Ra-228 ^a	NA	NA	NA	NA	NA	NA
Sr-90 ^a	15	35	0	NA	0	NA
Tc-99	15	35	0	NA	0	NA
Th-228 ^a	NA	NA	NA	NA	NA	NA
U-233/234 ^b	15	35	0	NA	0	NA
U-235/236 ^b	15	35	0	NA	0	NA
U-238 ^b	15	35	0	NA	0	NA
Total uranium ^c	15	35	0	NA	0	NA
Carbon tetrachloride	16	169	22	6.5 µg/L	2	M7S, RWMC Production
1,4-Dioxane	NA	NA	NA	NA	NA	NA
Methylene chloride	16	169	0	NA	0	NA
Nitrate ^b	15	34	0 ^c	NA	0	NA
Tetrachloroethylene	16	169	0	NA	0	NA
Trichloroethylene	16	169	12	2.6 µg/L	0	NA

a. Monitoring is not performed directly for the following analytes:

- Ni-94 is not a target analyte for groundwater and is, therefore, analyzed indirectly by gamma spectrometry analyses, if detected
- Ra-226 is not a target analyte for groundwater and is, therefore, analyzed indirectly by gamma spectrometry analyses, if detected
- Sr-90 is monitored indirectly through gross beta screening analyses.

b. U-234, -235, -238, and nitrate are naturally occurring in the environment, and the number of detections shown is for results that exceeded background upper concentration limits:

- Background upper tolerance levels for U-233/234, U-235/236, and U-238 are 1.92, 0.15, and 0.90 pCi/L, respectively; for nitrate, the applied upper concentration level is 5 mg/L.

c. Total uranium derived by converting isotopic uranium results (pCi/L) to mass units (µg/L) and summing the results.

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